With complements of the author

THE METALLIC INLAY.

BY

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WITH 158 ILLUSTRATIONS
AND 14 PLATES.

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To My Father,

C. F. W. Bödecker, D. D. S., M. D. S.,

This Book Is

Affectionately Dedicated.

Introduction.

The metallic inlay, and with it the general application of casting, is undoubtedly one of the most valuable acquisitions made by dentistry in the last few years. As a result of its success in practice, the gold inlay has become a recognized means of filling teeth. The fact that metallic inlays are indicated only in the posterior teeth, does not detract from their value, as in this position, the inlay is superior to all other classes of fillings.

The value of the inlay process was recognized many years ago; the material and the method of constructing the inlay itself, offered difficulties however. To the ingenuity of Taggart, in America, and of Solbrig, in Europe the dental profession is indebted for a metallic inlay which fulfills all just requirements.

The object of this book is to explain in a concise manner, the mechanical principles upon which the retention of metallic inlays depends; to apply these principles to the preparation of cavities, and to formulate a method of procedure in making and setting inlays. Though intended primarily as a practical guide, theoretical considerations could not be disregarded, as it is never wise to make a single step in any practical operation without knowing the theoretical reason.

In writing this book the arrangement of the German edition has been followed. It has been revised in some points, and a chapter on inlay abutments has been added.

The technique suggested, can by no means be considered complete. It is offered, so that others may improve upon it. If this little book in any way, directly or indirectly, should help in furthering the progress of the metallic inlay, the work of the writer will not have been in vain.

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Chapter I.

The Evolution of the Metallic Inlay.

Never will it be known to whom the honor belongs of having placed the first gold inlay in a tooth. Those who long ago practiced this method, kept their discovery a dark secret. Even the patient was not informed that the "gold filling" inserted, differed in any way from one made in the usual manner. Now, however, that the gold inlay has become a recognized means of filling teeth, the long guarded secret of the first gold inlays transpires. In all cases, the "method" was about the same. A large, imperfectly prepared cavity was laboriously filled with gold, the matrix removed and the filling polished. Before the finishing was completed, however, the whole filling had loosened. After some hesitation, the operator determined to reset the filling with cement, and at a subsequent sitting to polish the filling, — if possible, or, if necessary, — confess. If success attended the experiment, the filling was finished and booked in the journal with a question-mark. In how many cases this mark was justified will never be ascertained. There are, however, cases on record where such fillings have performed effective service for five, ten, and even fifteen years, as proven by patients presented at dental conventions.

I mention these cases only, to call attention to the fact that we have to-day examples which prove that the gold inlay can favorably compare in durability with the foil filling. But not only upon the inlays produced as the result of an accident, is our experience based, but also upon intentionally constructed inlays that were inserted many years ago. Since that time, a great number of methods for inlay construction have been proposed, but, especially in the beginning, a lack of interest prevented the profession at large

from adopting the inlay process. The introduction of porcelain as a filling material, however, resulted in the recognition of the advantages of the inlay. This material, extensively used for several years in all classes of cavities, is now limited to visible cavities in the anterior part of the month. During the porcelain era a certain number of men did not loose faith in the gold inlay. They experimented and perfected their methods, until the profession in general, dissappointed at the failure of porcelain in the posterior teeth, was willing to give the gold inlay a fair trial. The rapidity with which this method of filling has won new adherents in the last few years, is due less to the failure of porcelain, than to the increased simplicity in the production of the metallic inlay.

One of the oldest methods, in imitation of the inlays accidentally made, as described above, consisted in lightly filling the cavity with sponge-gold, carefully removing the whole, saturating with solder and resetting with cement. Numerous other methods soon followed, in which a matrix, as used for glass and porcelain inlays, played the most important part. The difference in these methods lay in the use of various kinds of foil, viz., gold, gold and platinum, and pure platinum; in the method of removing the matrix from the cavity; and in the use of gold of different karats for filling the matrix and for the production of contours and cusps.

The success attending the use of gold inlays in large cavities justified the attempt to use them for still larger restorations. The difficulty of building up such large contours and cusps with sponge-gold and solder, soon brought forth new methods. A matrix was made of thin 24 kar. plate. A cap, suitable for the case, was swedged on the die plate of a crown outfit and the requisite part soldered upon the matrix. In this manner the first hollow inlay originated. This procedure was soon improved upon in so many ways, that the hollow gold inlay can claim more methods for its construction than any other inlay filling, be it of gold or porcelain. In spite of these numerous methods, the construction of hollow inlays, instead of becoming simpler, became more and more complicated.

In the meantime the solid gold inlay had made progress.

The matrix, upon a model of the cavity, was filled with wax, tried in the mouth, replaced on the model, and the essential surfaces, that is, grinding surface and contactpoint, were smoothly covered with foil. The whole was then invested, leaving only the uncovered wax exposed. The latter was burned out and the resultant chamber filled with molten gold or solder. The next step was to neglect the foil covering, and to completely embed the matrix with its wax form. To produce a channel to the surface, a pin around which a cone of wax had been formed was stuck into the wax model. A vent was produced by a straw running from the model to the surface. The investment was then heated until the wax burned out. In a small depression beside the opening of the channel, the gold was melted with a blow-pipe. At the proper moment the mold was tipped, so that the gold flowed into the channel and into the mold. In this manner, as suggested by Solbrig (Paris), the first cast gold inlay, made by the wax dispersion method, was produced. To simplify the process, an electric furnace was constructed. It consisted of two parts; a lower, which could be heated to 600—700 ° F, for the reception of the mold, and an upper part in which the gold was fused. By removing a plug, the gold flowed down into the mold.

The finer details of the wax model could not, however, be reproduced without pressure. In the methods of casting employed in the arts, this is obtained by using a large amount of excess metal. As this is not practicable in casting gold, it was necessary to devise other means of obtaining sufficient pressure.

Dr. W. H. Taggart solved the difficulty, and in doing so inaugurated a new era in dentistry. Not alone was the construction of perfect inlays made possible, but also in crown and bridge-work, as well as in plate-work, has the value of casting become evident. The writer fully agrees with the words spoken by Solbrig at the Dental Congress held in Lille, 1909*. "In these various methods the construction of

*) Ash's Quartely Circular, Jan. 1910.

a matrix in gold or platinum was still indispensable, and it was Taggart, of Chicago, who first did away with it, by the application of pneumatic pressure in combination with the wax dispersion method. His merit lies not only in the ingenious invention of his apparatus, but also, and above all, in the influence which he exercised upon many colleagues with inventive minds, who were led by his enthusiasm and his success to make research in the same direction. Before his apparatus could be procured several other systems were pressed upon the notice of the profession, but not withstanding this Dr. Taggart must without doubt be considered the pioneer of the present period, as regards the casting of metals."

Chapter II.

The Advantages and Disadvantages of the Metallic Inlay Filling.

The interest which the dental profession has shown for the gold inlay during the past few years, proves that this method of filling teeth has steadily been gaining general recognition. The enthusiasts, however, go decidedly too far in claiming the method to be everywhere applicable. They recall the porcelain fanatic, who in answer to the question "Where is porcelain indicated?" replied, "On the hundred and sixty surfaces of the thirty two human teeth." Experience, sad to say, has taught us something different. Those who to-day predict that in the near future mallet, plugger, and gold foil will become relics of the past, may wait a long time for the fulfillment of their prophecy.

The truth of Franklin's motto: "A place for everything, and everything in its place," has been amply demonstrated by the filling materials introduced into dentistry in the past. I need only recall the fact that cement, amalgam and later porcelain, each at first indiscriminately used, are to-day confined to certain definite spheres of usefulness. That the metallic inlay will prove an exception to this rule, may be doubted, in spite of the many good qualities that this form of filling possesses.

The disadvantages of the above filling-materials are well known. Cement is more or less rapidly dissolved under the mechanical and chemical influences in the mouth. Amalgan often presents an unesthetic appearance, is liable to change its form, and under certain circumstances discolors the tooth. Porcelain, on account of the nature of the material, cannot be burnished against the margins of the cavity, and a seam, equal in width to the thickness of the foil used for the matrix, must therefore always remain. This seam constitutes the chief

disadvantage of the porcelain inlay. When in time the cement is dissolved at this point, the edges of the inlay being unsupported, chip off; they then become rough and often discolored. The ideal result, a restoration true to nature, is not attained under such circumstances.

The gold inlay is free from the imperfections mentioned in connection with the above filling-materials, but its construction requires a high degree of accuracy in order to produce a perfect filling. This fact has, by some, been considered a deficiency of the metallic inlay system. The success or failure of an inlay is determined by its adaptation to the cavity margin. The durability of an inlay is absolutely assured, if the space between the edge of the inlay and the enamel margin, is limited to the theoretical thickness of thinly-mixed cement. The possibility of producing such inlays has been demonstrated, but it is not probable that even the majority of gold inlays show such perfection at all their margins. Every operator should however remember, that in placing an imperfectly adapted gold inlay into a tooth, he is not only doing himself and his patient an injustice, but that he is also injuring the repute of a valuable filling-method, to-day on trial before the dental profession.

Before discussing the question of advantages, disadvantages, and general indications for the use of the metallic inlay, attention must be called to the functions of the cement. These are:

1. to intimately unite the inlay with the tooth;
2. to fill out all space between the inlay and the cavity wall.

The contention that in the same manner as the impression was removed from the cavity, the inlay itself may drop out if the cement does not happen to be sufficiently adherent, rests upon a misinterpretation of facts. Without here entering into a discussion of this subject (see Chap. III) it must be mentioned, that a truly adherent cement is not necessary. With almost any cement on the market, a metallic inlay can be firmly set in the cavity. Adhesion plays no essential part, as the attachment depends upon entirely different mechanical principles. The quality most desirable in a cement for this purpose is resistance to compression strain, i. e. crushing

strength. In order to utilize this property, the undercuts in the inlay and in the tooth must be in such relative position, that the inlay cannot be removed from the cavity without crushing the layer of cement. The shape of a properly formed inlay, materially aids the cement in preventing a displacement of the inlay. The topic of self-retention will be discussed in Chapter III.

The second function of the cement, the filling out of all spaces between the inlay and the cavity wall, has always been the point of attack of those opposed to all systems of inlays. To simplify the discussion of this question, it has been divided into two parts.

1. The office of the cement in the depth of the cavity, i. e., between dentine and inlay, and
2. The office of the cement at the margin of the cavity, i. e., between enamel and inlay.

The cement layer in the depth of the cavity should be as thick as possible. Especially is this necessary in large cavities in teeth with living pulps, in order to interpose a layer of thermally non-conducting material between the large mass of metal and the pulp. Besides this, a thick layer of cement is more advantageous in holding the inlay in the cavity.

It has been claimed by the opponents of inlay fillings, that thinly mixed cement cannot be considered a reliable filling material. As proof, they cite the disintegrated and evil-smelling cement sometimes found upon the removal of shell crowns that have been worn a long time. As proof to the contrary, mention may be made of the cement layer found upon the walls of those cavities out of which porcelain inlays have fallen. The hardness and density of the cement in such places leaves nothing to be desired. If putrefaction occurs, it denotes the presence of organic matter in the cement. This is possible only under two conditions. Either the cement is so porous that it can easily be permeated by the organic constituents of the saliva, or an admixture of saliva has taken place at the time when the crown was being set into place. The latter is by far the more reasonable assumption.

Besides mechanically filling out all spaces, the cement has

been proven to have a physiological action on the dentine. No other filling-material is capable of producing such marked changes through which the dentine becomes considerably more resistant to caries. The investigations of C. F. W. Bödecker upon the reaction of the dentine under various filling-materials, have amply proven this fact.*) Under oxyphosphate of zinc "the reaction is almost constantly present, and consists of a solidification of the dentine and an obliteration of a number of dentinal canaliculi. The dentinal canaliculi which are obliterated under oxyphosphate fillings first become faint, scarcely traceable and ultimately disappear, in consequence of which disappearance the fields of basis-substance between the dentinal canaliculi are considerably broadened . . . The consolidation is densest along the border of the cavity, where dentinal canaliculi are quite scanty; but the consolidated dentine extends to a considerable depth before it blends with normal dentine" (Fig. 1).

Upon the reaction of the dentine under gold fillings, the same author expresses himself as follows: "In some instances no reaction was noticeable in the dentine, only a zone of green colour, attributable to causes just mentioned under gutta-percha." (Due to coagulants applied before the introduction of the filling.) "In other instances there was a distinct reaction along the border . . . In still other instances the goldfilling has led to a partial obliteration of dentinal canaliculi similar to that induced by oxyphosphate of zinc, though never as complete as that which follows the introduction of the last-named filling-material." Under amalgam and under tin the reaction of the dentine is similar to that under gold. From these observations the great value of cement as a filling-material becomes apparent. It changes normal dentine, which is easily destroyed by caries, into a tissue which has the appearance and the resistance of so-called senile dentine. This is probably the reason why secondary decay hardly ever appears at the margin of a cavity filled with an inlay.

Opponents of the gold inlay have recently asserted, that as these observations were made in cases of teeth filled with

*) C. F. W. Bödecker, Anatomy and Pathology of the Teeth, page 323.

porcelain, the assumption that metallic inlays will show the same immunity to secondary caries is not justifiable. They believe in the possibility of an electric circuit being set up between the gold and the zinc of the cement, with the result, that conditions favorable for the beginning of caries would

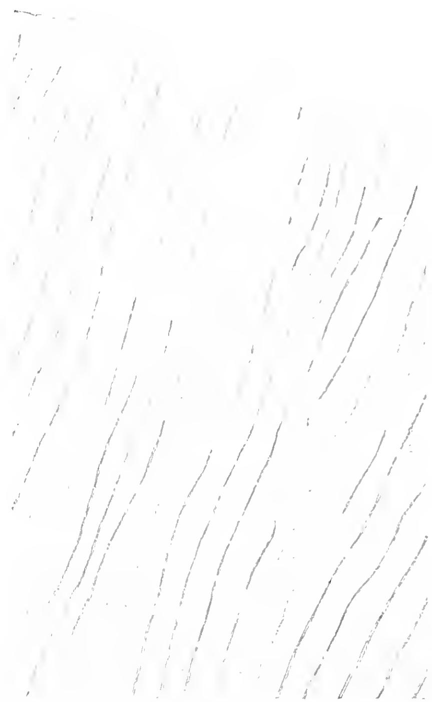

Fig. 1.

be produced. There is, however, no evidence in support of this theory, and it may be safely assumed that owing to the reaction of the dentine under the cement, secondary caries will be observed as rarely under a metallic inlay as it has been under porcelain.

In setting an inlay, more or less pressure is always exerted upon the thin cement. Whether this is sufficient to force the cement into the dentinal canaliculi and interglobular spaces,

and whether the reaction of the dentine is more marked than under an ordinary cement filling, are questions that cannot at present be answered, as the experiments conducted by the writer are not as yet complete.

The subject most important in all inlay methods will now be considered, i. e. the cement seam between the inlay and the margin of the cavity. Theoretically the width of the narrowest possible seam is equal to a single layer cement grains. The production of such a seam is possible only in certain places and under the most favorable circumstances. In discussing this question it will be assumed that the width of the seam is such as occurs with a well-fitting inlay, constructed according to the methods now in vogue. As in every other class of filling, the durability of an inlay depends upon the accuracy of its adaptation to the cavity margin. If therefore, an inlay, imperfect in this respect, is set into a tooth, its permanency is doubtful from the beginning. For the failure of such a filling, the inlay-process cannot be held accountable.

The durability of the cement is dependent upon the position of the seam on the surface of the tooth. Either it lies on, or near, the grinding-surface, where it is exposed to the pumping action of mastication, as it is named by C. J. Grieves*), or it lies toward the neck of the tooth, unaffected by this action. The conditions in the latter position will be discussed first.

In spite of claims to the contrary, cement, in time, dissolves more or less in almost every month. Exceptions to this rule are so rare that they may completely disregarded. This fact would apparently justify the assumption that the cement within the seam would in time be completely dissolved out. An examination of a large number of seams in positions unaffected by the pumping action of mastication has, however, proven, that *the cement is only dissolved out to a depth equal to the width of the seam.* This rule, it must be mentioned, does not hold good for seams exposed to the action of mastication.

The explanation of this fact, so important for the durability

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*) Dental Summary. Vol. 27, p. 93.

of the inlay, rests, according to C. J. Grieves and others, upon the protective action of the mucus present in the secretions of the mouth. All surfaces in the mouth, with the exception of those cleansed by mastication, are normally covered by a layer of mucus. W. D. Miller described mucin as a clear, viscous fluid, of alkaline reaction. It is albuminous, and therefore forms a nutrient medium for bacteria. It mixes with water, in the form of threads, without being soluble. It is insoluble in alcohol, ether, chloroform, and dilute acids; soluble in dilute alkalies and in concentrated acids. The layer of mucus on the teeth, containing albuminous bodies, offers the putrifactive bacteria of the mouth a suitable medium. As the reaction during putrifaction, at least in the first stages, is alway alkaline, the decomposition of mucus cannot act as a factor in the causation of caries.

The protective action of the mucus on the cement is explained by the fact, that mucin is insoluble in water and in dilute acids. As soon as the cement is dissolved out of a seam so far, that the mucus layer is no longer destroyed by the circulation of fluids during mastication, or in cleansing the teeth, the solution of the cement ceases. This, as has been already mentioned, occurs when the solution has proceeded to a depth equal to the width of the seam.

Some interesting investigations have been made upon this subject by J. Head*). He found that a seam filled with Harvard Cement, and placed in a one percent, watery solution of lactic acid, dissolved out in two to three days. The same material under the same circumstances, placed in a one percent solution of lactic acid in saliva, showed no evidence of being attacked. Head, also, believes this to be due to the presence of the mucin in the saliva.

If the seam lies on the occlusal surface, the above mentioned rule does not apply, because the pumping action of mastication, as well as the mechanical contact of the food, prevents the formation of a sufficiently thick layer of mucus. This evil, the most dangerous of all, for the inlay process,

*) Dental Cosmos Vol. XLVII, p. 789.

has been the subject of much thought, and many experiments. It is evident that in this position the width of the seam must be confined to its theoretical minimum. The narrower the seam, the less disturbance can be caused by the pumping-action, and the stronger is the action of the capillary attraction holding the mucus layer in place.

To make such seams less vulnerable, bevelling the cavity margin has been suggested. The success of this measure alone may be doubted, as the seam remains exposed to the pumping action. The author beleives that the only possible protection against the solution of the cement in this place, is an almost theoretically perfect adaptation of the inlay to the cavity margin.

For this reason the author adheres to the use of 24 kar. gold in the construction of inlays. With this material it is easy, especially on the occlusal surface, to force the gold against the margin of the cavity with a tomato-burnisher. The disadvantages of 24 kar. gold are: that high cusps cannot be built up in case of a sharp bite; that it does not take as smooth a polish as 22 kar.; and that considerably higher heat is necessary in casting. The objection, that an inlay of 24 kar. gold is much softer than a hammered foil filling, does not affect its usefulness. If a pure gold inlay, which is a trifle too high, is examined in the mouth, it will show that the area constantly struck by the antagonist, is harder than any foil filling.

The time necessary for the construction of an inlay has, by some, been considered as an objection to inlay methods. If, however, the inlay is used only where large surfaces, contours, or cusps are to be restored, this process offers a decided saving of time.

Another apparently more justifiable objection is, that all inlays require an extensive sacrifice of healthy tooth-structure. If by this is meant a thorough cutting out of the fissures, then it can only be of advantage in protecting the tooth from redecay. If it refers to the ruthless destruction of tissue, simply to make the removal of the impression easy, or to produce a typical box-shaped cavity with steps and squared angles, then the objection is more than justified. An inlay

cannot be made in quite such narrow limits as an amalgam, or an ordinary gold filling. But if we compare the cavity-preparation of a conservative inlay operator, with a cavity prepared according to the teachings of Black, but little difference in the extent of the cavities will be found. In some cases it will even be in favor of the inlay (see Chap. V).

The advantages the tooth derives from the use of the inlay are briefly as follows:

1. The cement causes a reaction in the dentine, making it more resistant to decay.
2. The cement forms an insulating layer, which protects to pulp from rapid changes of temperature.
3. The cement, intimately uniting the inlay with the tooth, gives support to weakened walls.
4. The cement adheres to dry dentine, so that in the case of self-retentive inlays, under cuts, if properly placed, need not be very deep at excessively sensitive places.
5. Very weak walls which are liable to fail later may be removed, as the work of constructing an inlay does not depend upon its size.
6. Prolonged malleting, which often causes a hyperaemia of the pulp or a slight pericementitis, is avoided.
7. The danger of fracturing a wall, due to the expansion of the filling under the mallet, as well as,
8. The danger of injuring the enamel margin with a plugger, cannot occur with an inlay.
9. Contours and contact-points of inlays are more easily built up, and preserved while finishing, than those of fillings made in the mouth.
10. Cusps with proper articulation can be readily produced on an inlay.
11. The filling is of a uniform density. Hollow spaces are not present, and the surface is smooth. An exfoliation, as is often the case with foil fillings, does not take place; food particles, etc. can therefore not adhere.
12. Over porcelain, the metallic inlay has the advantage, that the seam is not increased in width by the removal of the matrix.

13. The use of the metallic inlay enables us to fill cavities with gold, which on account of their unfavorable position, cannot be filled with a foil filling. For example, cervical cavities extending deeply under the gum, where the use of the dam is not possible.
14. Many extensively decayed teeth, upon which shell-crowns are usually set, may do good service for years, if restored by means of a metallic inlay.

For the patient also, the inlay process offers conveniences which he soon learns to appreciate.

1. The time consumed by the work in the mouth is considerably shortened.
2. The use of the mallet, the rubberdam and its accompanying evils, the ligature and the clamp, are avoided.
3. Separators are applied less often.
4. Setting an inlay takes no longer than introducing an ordinary cement filling.
5. The operation of filling a tooth with an inlay, may be discontinued at more stages than with other fillings.

Besides being more agreeable to the patient, the inlay process offers certain advantages to the operator. In case of large fillings, a saving of time is effected. But the chief value is, that the operator, knowing to a certainty whether the filling he has placed into a tooth is perfect or not, can foretell its durability more positively than if he had used any other filling material.

The indications for the use of metallic inlays are briefly the following:

1. In all larger cavities where a sufficiently direct and free access for the introduction of a foil filling cannot be obtained. Such are the cavities on the distal surfaces of the bicuspids and molars. In cases of extensive decay, the inlay may also be used on the mesial surface of these teeth.
2. Large defects of the grinding surface, requiring a restoration of the cusps.
3. In all cervical cavities extending beneath the gum in the molars, and, exceptionally, in the bicuspids.

4. To make large restorations on the teeth of children and nervous patients.
5. In cases of so called soft teeth, where secondary caries usually appears at the margin of the most carefully introduced metallic fillings.
6. In building up abraded cutting edges of the incisors and cuspids.
7. In teeth loosened from any cause.
8. Teeth loosened by pyorrhea may be supported by soldering together a series of proximal inlays at their contact points.
9. Interproximal spaces into which the food easily packs, may be restored to normal conditions, by inserting inlays with exaggerated contours.
10. As bridge abuttments, various inlays have been suggested and some successfully used.
11. In orthodontia, inlays alone or in connection with an apparatus may occasionally be used to retain the teeth.
12. In making shell crowns, the true bite may be obtained, by modelling wax onto the band in the mouth, investing, and casting the occlusal surface directly onto the band.

In spite of the number of indications mentioned above, it is to be doubted whether the result would be a success in every case. The chief disadvantage of the inlay process, the difficulty of producing perfect adaptation at the cavity margin, would justify the assumption that it is almost impossible to solder a number of inlays together without endangering their perfect adaptation to the margin of the cavity. As a filling method, however, the metallic inlay process deserves full recognition, if its application be limited to filling larger cavities of the bicuspids and molars.

Chapter III.

Retention of Metallic Inlays.

The durability of an inlay is largely dependent upon its mode of attachment to the tooth. In porcelain inlays the chief reliance was placed upon the adhesive qualities of the cement. In the case of the metallic inlay, however, the cavity may be so prepared that the inlay receives support in every direction except in that, opposite to the one in which it was inserted into the cavity. If this direction is parallel to that of the pressure of mastication, the inlay cannot be bitten out of the cavity as long as the tooth remains intact. The possibility of giving the cavities such a favorable form is due to the fact that metal, in contradistinction to porcelain, is sufficiently resistant to the force of mastication, to permit the construction of comparatively thin anchorage-extensions, fitting snugly into the fissures and grooves of the tooth.

The retention of the finished inlay should be considered in the early stages of cavity-preparation. Before beginning with the excavation of the dentine, the direction and amount of the force of mastication must be studied, and the position determined, where sufficient anchorage may be obtained on the tooth. Which form of anchorage should be chosen in a given case, depends upon the position and the depth of the cavity, upon the structure of the tooth itself, and upon the distribution of the healthy tissue about the cavity.

The writer has divided the retention of inlays into two classes:

1. Retention depending upon an intermediary body. (Cement-retention.)
2. Retention depending upon the form of the inlay itself. (Self-retention.)

Cement-Retention.

Retention Depending upon an Intermediary Body.

The material used for the attachment of metallic inlays is oxyphosphate of zinc cement. Sufficient data has been gathered during its use in connection with porcelain inlays, to prove that this material possesses the necessary qualities for setting metallic inlays. The fact that thinly mixed cement adheres to dentine is generally recognized, but the explanations regarding it differ. It has been claimed, that a chemical union takes place. A more probable explanation is that the acid, corroding the dentine, produces a rough surface on which the cement obtains a purely mechanical hold. However this may be, the cement is sufficiently adherent to the dentine for the purpose of retaining the inlay in a cavity. The hold which the cement finds on the surface of the inlay is purely mechanical, and should be the subject of special attention. This hold may be produced in two ways, either by deeply undercutting with a saw or knife-edged stone, or by roughening with a pointed instrument. Which of these two methods is to be used in a given case, depends on the following circumstances. If the free surface of the inlay is comparatively larger than that within the cavity; or if the inlay is exposed to the force of mastication without itself having sufficient self-retention; or if the cement layer between inlay and cavity-wall is very thin, deep undercuts are to be used. A general roughening of the surface, being easier to produce than the undercuts, is indicated where the latter are deemed unnecessary.

The Undercut.

If deep undercuts are to be made use of, they should be so placed that those in the inlay lie exactly opposite to those in the walls of the cavity (Fig. 2). The retention of the inlay is dependent in this case, upon a ring of cement whose strength is proportional to the compression-strength of the cement, and to the thickness of the ring. If the undercuts in the inlay and in the tooth are exactly opposite each other, the force necessary to dislodge the inlay is equal to that which could

crush a layer of the thickness a—b (Fig. 3 A) of the cement used to set the inlay. If the undercuts are not quite opposite one another, the effective thickness of the ring is reduced

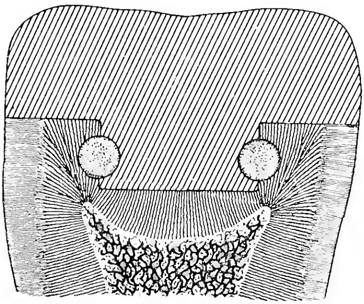

Fig. 2.

to c—d (Fig. 3 B). In case no parts of the undercuts face each other, they become practically useless. The cement lying in the undercut in the tooth (II, Fig. 3 C) finds little or no hold

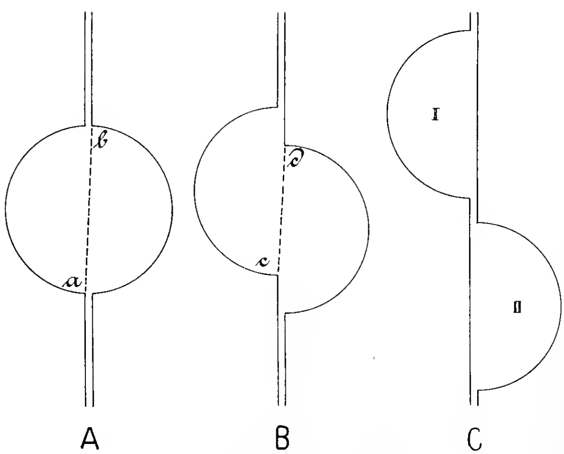

Fig. 3.

on the inlay. This undercut is therefore superfluous. Owing to the fact that thinly-mixed cement adheres to dentine, the cement in the undercut in the inlay (I, Fig. 3 C), finds some hold on the cavity wall. The retention so obtained is, however,

not comparable to that of a ring of cement, or that produced by a general roughening of the surface of the inlay.

As experience has shown the difficulty of bringing the undercuts in exact apposition, a more certain method of transmitting the pressure from the inlay to the tooth is required. By thickening the layer of cement between the inlay and the cavity walls at certain points, a more uniform distribution of pressure is obtained. This is accomplished by a further

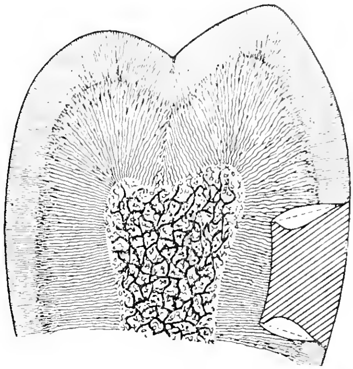

Fig. 4.

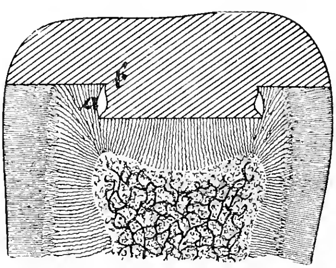

Fig. 5.

excavation of the walls of the cavity; this in most cases obviates the necessity of making undercuts in the tooth (Fig. 4). In a cavity such as Fig. 5, a deep undercut at *a*, would appreciably weaken the edge *b*. A slight excavation, as shown, would be equally effective in anchoring the inlay. It may be stated here as a general rule, that undercuts with

square angles (Fig. 9 B and C) alway weaken a structure more than if these angles were rounded (Fig. 10).

All undercuts made into an inlay must be of proper form and in their theoretically correct position. To understand this correct form and position, the part played by the cement in the retention of an inlay must be studied. Its chief function will be made clear by the following: Two metal parts with holes drilled at *a* and *b*, are suspended as shown in Fig. 6.

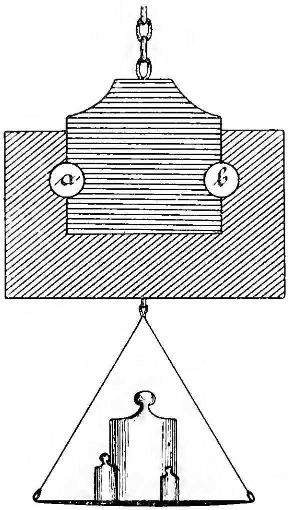

Fig. 6.

If *a* and *b* were filled with exactly fitting metallic rods it would be almost impossible to separate the parts. If the holes were filled with cement, plaster, sealing-wax, or rosin, the weight necessary to separate the parts would vary with each substance.

The moment that the separation of the parts begins, a change of form of the holes *a* and *b* takes place (Fig. 7). If the holes are filled, the filling must bear the weight of the whole mass placed on the scale-tray below. The diameter of the hole, *a—b* (Fig. 8 *a*), tends to diminish, and pressure is therefore exerted upon the filling material in the direction *a—b*. At the same time the diameter *c—d* elongates, so that the

filling material looses its support in this direction. As long as the filling-material possesses sufficient resistance to compression, i. e. crushing strength, to prevent a change of form of its mass, no movement of the parts can take place. The value of a material for this purpose is therefore dependent upon its crushing strength.

The pressure which a material can bear is dependent upon the area subjected to pressure, as well as upon the thickness of the material itself. These facts must be taken into consideration in determining the form and position of an undercut.

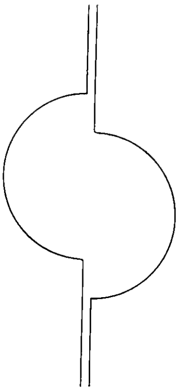

Fig. 7.

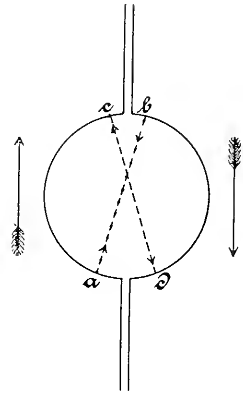

Fig. 8 a.

In selecting the position, leverage by which the inlay might be pried out of the cavity during mastication, must be taken into account. As the margin of the cavity acts as a fulcrum, it is evident that the farther the undercut (hold) is away from the margin of the cavity, the greater will be the force necessary to dislodge the inlay. For this reason, undercuts are to be placed near the floor in simple cavities.

The difficulty of bringing the undercuts in the tooth and in the inlay in apposition has already been mentioned. By changing the form of the undercuts and widening the cavity in certain places, a more favorable distribution of pressure in the cement layer can be brought about. Fig. 9—12 are enlargements of the shaded portion of Fig. 8 b. Fig. 9 shows the

wall of a cavity slightly enlarged at A, and having an undercut made with a wheel at B. The inlay is undercut with a saw at C. If an attempt is made to remove the inlay in the direction of the arrow, pressure will be set up in the cement layer. The main pressure between inlay and tooth will be born by a cone of cement, of the form, *a b c d*.

The resistance which the cement offers, depends mainly upon the direction of the pressure cone *a*—*d* in relation to the direction in which the inlay may be removed from the cavity. The more nearly these two directions correspond, the more does the cement depend upon its crushing strength for the retention of the inlay. Another factor determining the

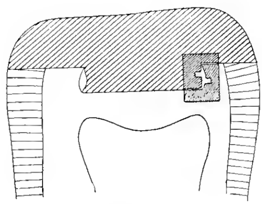

Fig. 8 b.

effective resistance of the cement, is the area of the cross-section of the pressure cone. Other things being equal, the larger the area, the stronger the retention.

A consideration of Fig. 9, will show, that the undercuts C and B could have been made less deep, without thereby decreasing the sectional area of the pressure cone; that is, the inlay would have been equally resistant, if the undercuts were of the form *a*, *b*, *c* and *e*, *d*, *c*. It also becomes apparent, that if the corner *e* were removed, the pressure cone would gain in cross-sectional area, and at the same time lie in a considerably more favorable direction. The cement in the depths of the undercuts C and B takes little or no part in the retention of the inlay. Fig. 10 shows the undercuts, correct in form and position; the points discussed in Fig. 9 having been practically applied. The corner *e* (Fig. 9) has been removed, and the pressure cone, now filling out the entire space, has thereby been widened and brought into a more favorable direction.

The undercuts are less deep, and have no sharp angles. The latter is, however, of less importance with metallic than with porcelain inlays. The form of undercut in the tooth, Fig. 10, weakens the wall far less than one made with a wheel. The lower part of the undercut in the inlay, has been cut obliquely so that the pressure cone rests at right-angles upon the surface of the inlay.

A further advantage of this form of undercut is the following. It is a known fact that most cements expand while

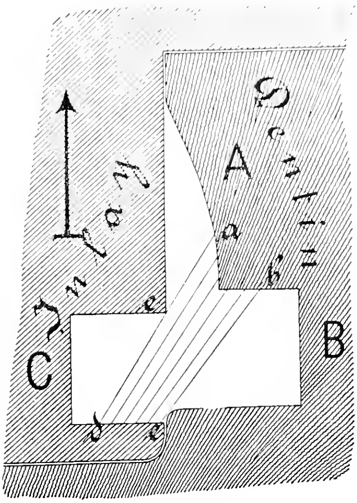

Fig. 9.

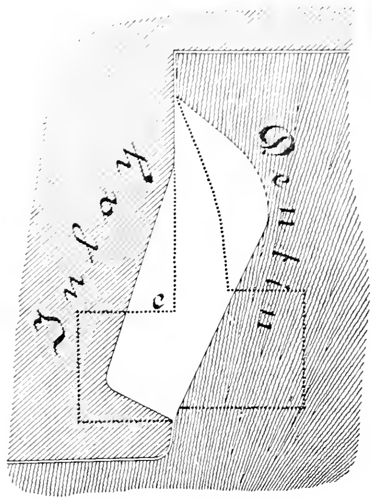

Fig. 10.

setting.*) This causes the inlays, set with such cements, to rise out of the cavity to a greater or lesser extent. If, however, undercuts, correct in form and in relative position be used (Fig. 10), an expansion of the cement does not force the inlay out, but on the contrary, presses it more firmly into the cavity. In such cases attention should be paid to the fact, that the mass of the cement must be contained in the undercuts, the cement at all other points being limited to the thinnest possible layer.

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*) See Poundstone's table p. 140.

Where the undercut in the inlay lies above that in the tooth (Fig. 11), the pressure-cone finds but little hold upon the almost vertical wall of the cavity. The retention of the inlay in this case does not depend upon the crushing strength, but almost wholly on the tensile strength of the cement. Tension, like compression, spreads through a mass in the form of a cone. Therefore, in the cement layer of Fig. 11 a tension-cone will extend from the undercut *a*—*b* in the direction *c*.

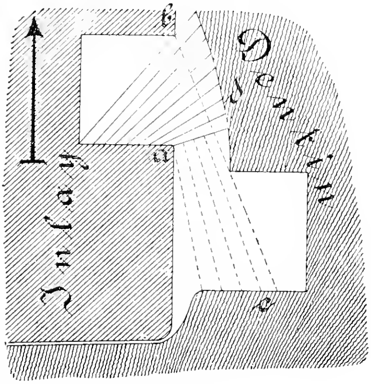

Fig. 11.

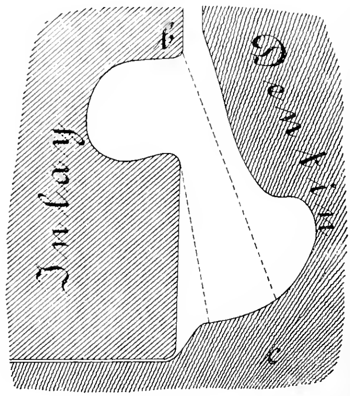

Fig. 12.

The cross-sectional area at *a* is too small to give sufficient retention to the inlay. As the tensile strength of cement is far lower than its compression, or crushing strength, the sectional area of the tension-cone must be far greater than that of the pressure-cone to give the same retention. Besides this, it is necessary to make regular undercuts in the tooth as well as the inlay, as the adhesive qualities alone can not be depended upon (Fig. 12).

Roughening the Surface.

The second method of producing a hold for the cement is by roughening the under surface of the inlay with a sharp instrument. Hersey*) recommends the Bonwill mallet. Any

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*) G. S. Hersey, Dental Cosmos, Nov. 1906, p. 1167.

mechanical mallet with a sufficiently strong blow can be used. The writer has had the best and quickest results by using a sharp instrument in the mechanical engraving instrument, shown in Fig. 113.

If the cement layer is thin, the blows must fall at right-angles to the surface, so that the roughening consists of innumerable depressions placed close to one another. An enlargement of one of these depressions is shown in Fig. 13. Where the cavity has been widened, the point of the instrument is applied obliquely to to surface, and small step-like projections are thrown up (Fig. 14). The projections should be

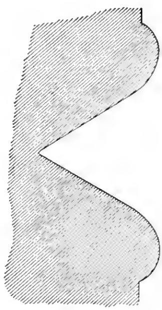

Fig. 13.

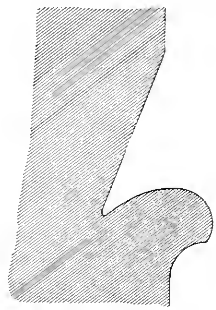

Fig. 14.

miniature reproductions of the undercut shown in Fig. 10. The step should always face the direction in which the inlay can be removed from the cavity, so that the retention may depend upon the crushing strength of the cement. A slight widening of the cavity, below the margin, is the only treatment the tooth requires before setting the roughened inlay. Regular undercuts into the dentine are unnecessary.

The retention of a roughened inlay depends upon the number and size of the pressure-cones produced by the projections. These in turn are dependent upon the area of the surface of the inlay within the cavity. A roughening is therefore indicated in proximal, cervical, and labial inlays, as they are not exposed to mastication and their free surface is always less than that within the cavity. Proximal inlays in molars and bicuspids may be roughened if they are sufficiently an-

chored by means of self-retention. Regular undercuts are, however, to be used in the restoration of incisive edges, corners, and cusps.

Upon what might be called accidental retention, rests the explanation of the durability of so many inlays, gold as well as porcelain, that have been set in improperly prepared cavities. Upon the dentine the cement always finds sufficient hold. On the inlay there are usually present, in smaller or greater numbers, projections accidentally formed. If some of these are favorably placed, the cement finds a support to resist compression. The strength of such retention is very small, and being a matter of chance, should be totally disregarded.

Retention by means of cement may always be depended upon if employed only in cases where it is indicated. The preparation of the cavity must be correct, and there should be a mechanical reason for the position of each undercut. The practice of indiscriminately under-cutting both tooth and inlay is unscientific, and is probably the cause of .many failures.

Self-Retention.

Retention Depending upon the Form of the Inlay Itself.

Inlays of this description are confined almost exclusively to the molars and bicuspids. The hold, or anchorage of a self-retentive inlay must be so located, that, without depending upon the retentive power of the cement, it can easily resist the forces which tend to dislodge the inlay during mastication. The extent of the hold, which the inlay finds upon the tooth, is of less importance than its location. A slight hold at the proper place, is more valuable than a stronger anchorage at a point where it can not counteract the forces which tend to dislodge the inlay. Though all so-called self-retentive inlays do not strictly fulfill the above requirements, they nevertheless are anchored in more directions than inlays depending entirely upon cement-retention.

The strength and the direction of the force acting upon an inlay, are dependent upon the size and form of the occlusal

surface. The direction of the force is of prime importance. If the antagonist strikes the oblique occlusal surface of the inlay (Fig. 15), force will be exerted in two directions; toward the middle, and toward the neck of the tooth. The more oblique the surface, the greater will be the pressure forcing

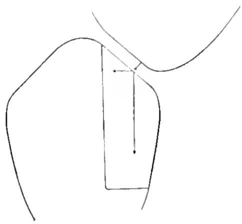

Fig. 15.

the inlay into the cavity. This fact is of practical significance if two adjoining proximal cavities are to be filled with inlays. As in this case the position of the contact points is not predetermined, they may be placed slightly nearer the cervical margin than normally, thereby giving the inlay a decidedly more oblique occlusal surface (Fig. 16). Such a procedure

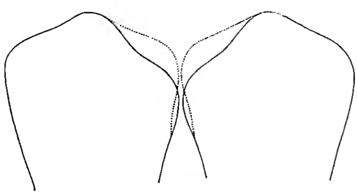

Fig. 16.

is valuable in filling bicuspids extensively destroyed by caries, as it obviates the necessity of cutting deeply into the weakened walls in order to obtain complete anchorage by this means alone.

If the occlusal surface is horizontal, as in the case of the molars, simply closing the jaws will force the inlay against the cervical margin, while the masticatory movements will tend to tip the inlay out of the cavity. To prevent such dislocations, the inlay must be formed so that it finds a hold

upon the tooth. In order to determine the exact location of this hold or anchorage, the different phases during the dislocation of an inlay must be understood. The inlay may be dislodged in two ways, depending upon the shape of the cavity. If the wall at the cervical margin is narrow (Fig. 17), the inlay is insufficiently supported against vertical pressure. It

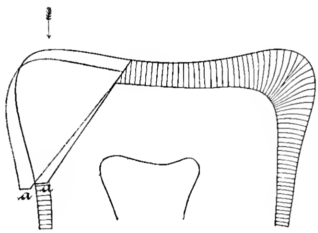

Fig. 17.

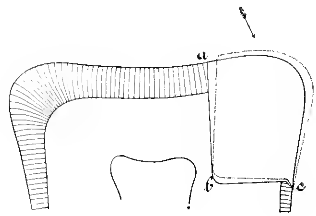

Fig. 18.

may then be forced out of the cavity, as on an inclined plane, and the margin *a* at the same time fractured. In the second case, where the wall is wide enough to give support against the vertical pressure, forces acting obliquely produce a leverage which tends to tip the inlay out of the cavity (Fig. 18). The

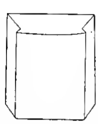

Fig. 19.

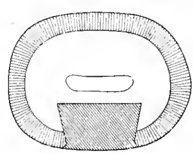

Fig. 20.

cervical margin always acts as the fulcrum. To successfully oppose this leverage, is the function of a self-retentive inlay.

To a limited extent, porcelain inlays of this description have been made. In Stockholm, in 1902, N. S. Jenkins showed such a porcelain inlay made by Ottolengui (New York). The inlay (Fig. 19) was compact, without thin processes or extensions. On account of the brittleness of porcelain this was the only form possible for a self-retentive inlay made of this material. Though this cavity form (Fig. 20) was very ingenious, it was not applicable to larger cavities, as in such cases suffi-

cient tooth-substance was lacking. The difficulty of preparing such cavities has caused this form to be discarded. For metal inlays other forms, more satisfactory and easily made, have been adopted.

Metal, in contradistinction to porcelain, not being brittle, permits the construction of thin processes and extensions which firmly anchor the inlay into the tooth.

Groove Anchorage.

In considering the action of the leverage shown in Fig. 18, it becomes apparent, that the dislocation is greatest at *a*, and gradually decreases toward the point *b*. If this fact is

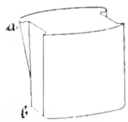

Fig. 21.

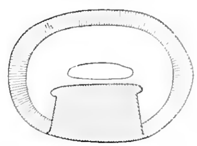

Fig. 22.

practically applied, an inlay of the form shown in Fig. 21 will result. The extension is strongest at *a*. This, the point of greatest movement during dislocation, is farthest away from the fulcrum, and is also most easily accessible in cutting the groove into the cavity wall. The extension need not be carried to the point *b* as sufficient anchorage can be obtained at *a*, to firmly lock the inlay in the cavity (Fig. 22).

Fissure Anchorage.

If the lateral walls of a proximal cavity are weak or entirely absent, or if the fissures in the occlusal surface require filling,

Fig. 23.

the anchorage mentioned above should not be used. In such cases the fissure-anchorage is indicated. The fissure is excavated until a fissure running in a bucco-lingual direction is reached (Fig. 23). This is excavated in one or both directions. If a fissure of this description is not present an artificial one running in this direction must be made.

Hook-Anchorage.

This form of anchorage is indicated in cases where the occlusal surface has been almost entirely destroyed (Fig. 24),

Fig. 24.

and where at the same time the lingual or buccal wall is lacking. With a thin disk-wheel a groove is cut into the occlusal surface of the remaining wall. At its outer end the groove is extended vertically for a short distance (*a*, Fig. 25).

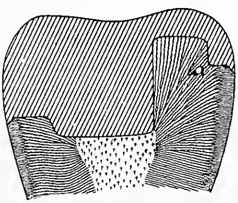

Fig. 25.

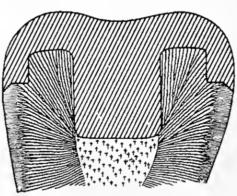

Fig. 26.

The resultant inlay then has a hooklike process, which prevents any dislocation through the forces of mastication. If two opposing walls are standing, the double hook-retention not alone anchors the inlay, but it also gives support to weakened walls (Fig. 26). This form of anchorage is of value in pulpless molars, where the proximal surfaces have been extensively destroyed by caries, and the weakened buccal and labial walls still remain standing.

Dove-tail Anchorage.

This is a modification of the form just described. Strength is the first requisite of the wall into which such an anchorage is placed. The dove-tail cavity should have walls (*a* and *b*, Fig. 27) parallel to the direction in which the inlay may be

Fig. 27.

removed from the cavity. The floor of the cavity (*a*, Fig. 28) should incline, from within outward, toward the neck of the tooth. The segment *c* (Fig. 27) of the inlay should be sufficiently strong to prevent stretching of the metal at this point, under the force of mastication. If the body of the inlay is firmly seated (Fig. 28), thereby resisting all vertical pressure,

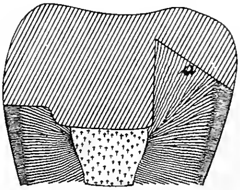

Fig. 28.

the segment *c* need not be excessively strong. If, however, the floor of the main cavity is narrow or sloping, the segment must resist the vertical as well as the oblique forces of mastication, and must therefore be accordingly strong. The preparation for the dove-tail anchorage is made with a knife-edged stone, and the resultant inequalities in the floor finished with a thin wheel. For larger inlays, this is the most easily and quickly made form of anchorage; a strong wall is, however, always necessary.

Anchorage through Combination of two Cavities.

Inlays having this form of anchorage are used in filling molars, and more often bicuspids, with cavities on both

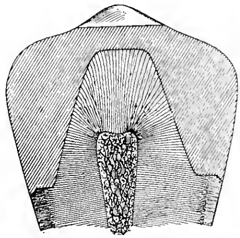

Fig. 29.

mesial and distal surfaces (Fig. 29). The same applies to inlays extending over the cutting edges, of the incisors and cuspids.

Reciprocal Anchorage of two Inlays.

If one or both of the proximal cavities in a molar or bicuspid extend to the neck of the tooth, it is preferable to obtain retention by means of reciprocal anchorage of two inlays. This method has several advantages. As two impressions are taken,

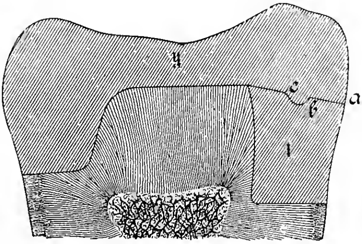

Fig. 30.

each may be removed in the direction most convenient. If a single impression of both cavities were to be taken, much healthy tooth structure would, in most cases, have to be sacrificed in order to allow the impression to draw. Another point is the difficulty of making a perfect inlay which involves three surfaces of a tooth.

The procedure of combining two inlays is as follows (Fig. 30).

An impression is taken of the more difficult cavity. The inlay I, should not extend to the occlusal surface. At *b*, a depression should be made, and the surface sloped in the direction *a*. This is done upon the wax-model. The inlay is then completed and set into the cavity and an impression of the remaining part of the cavity taken. The second inlay II, Fig. 30, is made and set in the usual manner. By means of the projection *c*, and the inclined surface *a*, the second inlay anchors the first in the tooth. The second inlay is itself anchored by the projection and the inclined plane as well as by the hold it finds on the walls of the fissures and in the second cavity.

Pin-Anchorage.

Another form of retention which may be used in double as well as single inlays, is the pin-anchorage. At the proper

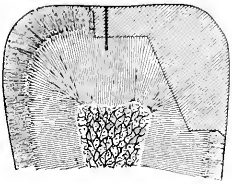

Fig. 31.

point, a canal is drilled through the inlay into the one lying beneath, and into this a pin of suitable size is set with cement.

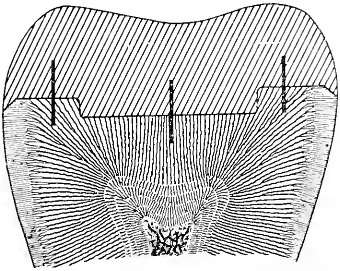

Fig. 32.

For double inlays the projection described above is preferable, as it is easer to construct and does the same service. This form of anchorage may, however, be used where other methods

are not easily applicable, as in restoring the corners of incisors (Fig. 31). In certain forms of inlay bridge-abutments this method of anchorage has been employed. The principal use of the pin-anchorange is in restoring the abraded surfaces of molars and bicuspids. The pins are let into the tooth, and removed with the impression. The inlay is then cast onto the pins (Fig. 32). In the experience of the writer, German-silver has proved to be the best material for such pins. In casting, the gold forms a perfect union with this metal.

Chapter IV.

Retention and Cavity-Form.

The practical application of the different forms of anchorage will be discussed in a later chapter. The fundamental principles of retention, which must be considered in the preparation of every cavity, should be perfectly well understood by those doing inlay work.

The cavity for an inlay should be so prepared, that the wax model or the impression may be removed without distortion, and that the inlay may find sufficient hold on the tooth to resist the force of mastication. This hold should, whenever possible, depend upon the shape of the inlay, and

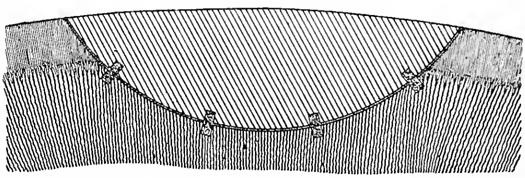

Fig. 33.

not upon an intermediary binding-material, such as cement. In complex cavities this requirement is easily fulfilled. In simple cavities the conditions are, however, somewhat different.

When porcelain inlays were first introduced, many operators, gave the cavities a saucer-shaped form, assuming that the adhesion of the cement would keep the inlay in position. Numerous failures occured; but these were ascribed to inequalities in the adhesiveness of the cement. A consideration of Fig. 33 will show that the position of the undercuts in a saucer-shaped cavity are most unfavorable for cement-retention. The walls of the cavity, and therefore also the sides of the inlay, lie obliquely to the direction in which the inlay

may be removed from the cavity. (Fig. 34. An enlargement of an undercut in Fig. 33.) The undercuts in the inlay are placed above those in the tooth; a condition which has been described in discussing Fig. 11 and 12. The retention of the inlay is therefore entirely dependent upon the tensile strength of the cement. This is probably a truer explanation of the failures than the assumption of differences in the adhesive qualities of the cement.

To avoid these failures, it was then suggested to prepare the cavity in the shape of a box, and to confine the thickness

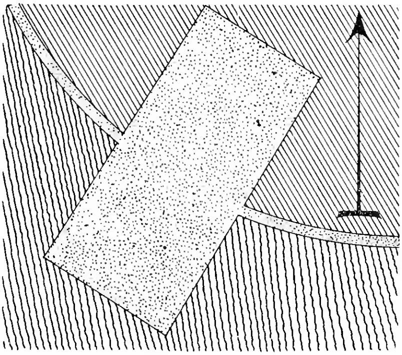

Fig. 34.

of the cement layer to a minimum. This procedure undoubtedly gave the inlay a sort of self-retention. The box-shape was then adapted to other cavities. By far the greater majority of the authors writing upon the subject of cavity preparation for gold inlays, have recommended the box-shape, strictly carried out, for complex cavities in molars and bicuspids. This necessitates extensive cutting into healthy tooth structure and has, as a result, caused many operators to disapprove of the metallic inlay as a means of filling teeth.

Before entering into the question of the proper thickness of the cement layer, the influence of the box-shape on retention will be discussed. As the conditions for cement-retention in saucer-shaped cavities are unfavorable, and the inlay itself has no anchorage in the tooth, direct pressure on its surface

will force the inlay it out of the cavity (Fig. 35). If the cavity is box-shaped, the inlay cannot be dislodged in this way (Fig. 36). Not alone does the inlay here find a hold in the cavity, but the conditions for cement-retention are as perfect

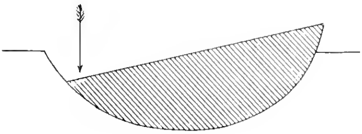

Fig. 35.

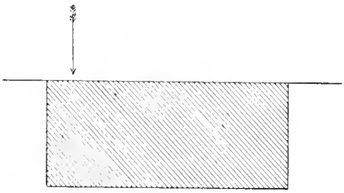

Fig. 36.

as possible. The theoretically correct undercuts (Fig. 10) may be employed, with the certainty that the cement-retention will not fail. The success of this form of cavity is based upon the fact, that *the walls of the cavity lie parallel to the direction in which the inlay can be removed from the cavity.* This fundamental rule should be observed in the manner described later, in preparing all inlay cavities.

"Box-shaped" does not suggest the same form to every operator. A cavity such as Fig. 37, has been so designated.

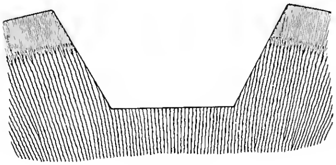

Fig. 37.

But in spite of the straight walls and vertical floor, such a cavity possesses most of the physical characters of the ordinary saucer-shaped cavity. According to the opinion of the writer, the characteristic feature of the box-shaped cavity, is *the presence of walls, parallel to the direction of removal of the inlay* (Fig. 38). The general form of the cavity is immaterial. The floor need not be horizontal, nor need the angles at this point be sharp, as usually shown in illustrations.

There are some places where it is impossible to prepare a cavity box-shaped, in the strictest sense of the word. Such a cavity with four parallel walls cannot be cut into the neck

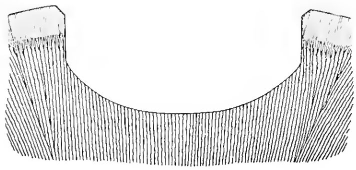

Fig. 38.

of a bicuspid (Fig. 39). The upper and lower walls of the cavity (*a* and *b*) may be made parallel, but the lateral walls (*c* and *d*) must converge in order to be at right-angles to the surface of the tooth. These walls are therefore not suitable

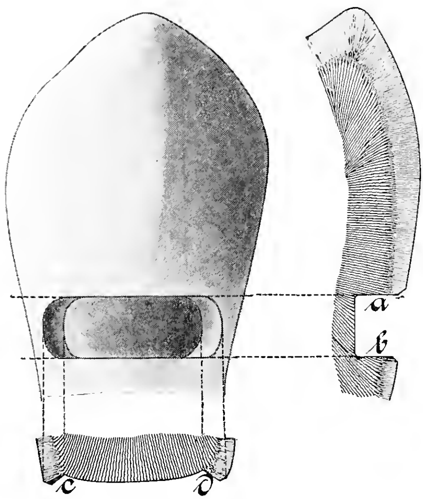

Fig. 39.

for cement-retention. The walls *a* and *b*, lying opposite each other, have the proper direction and are of considerable length. If these are correctly undercut, sufficient anchorage for cement-retention will be obtained. If the pulpal wall of the cavity *c*—*d* (Fig. 39) is convex or even straight, and it is not deemed advisable to further weaken the neck of the tooth

by extending the cavity (Fig. 40, *a*), another method of preventing lateral dislocation may be used. At *a* and *b*, Fig. 41, broad notches are cut into the inlay. These should lie at right-angles to the direction in which the inlay can be dislodged. If the pulp is sufficiently distant, grooves (*e* and *f*, Fig. 42) may also be cut into the tooth. The latter should

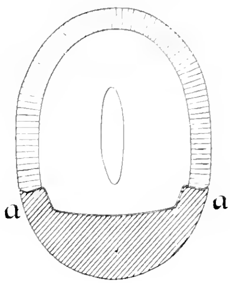

Fig. 40.

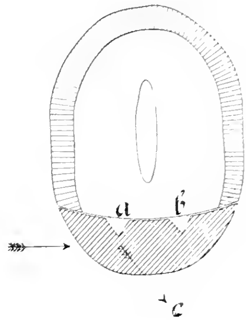

Fig. 41.

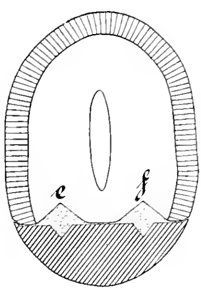

Fig. 42.

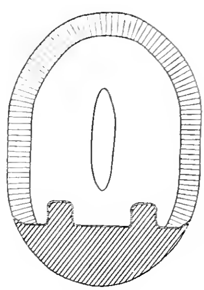

Fig. 43.

be wider than those in the inlay, to allow for the difficulty in bringing these undercuts into exact apposition. The cement filling out the grooves acts as an inclined plane, changing the direction of pressure applied laterally, so that the inlay seeks to escape in the direction *c*, (Fig. 41). The cement-anchorage on the upper and lower walls (*a* and *b*, Fig. 39), is sufficiently strong, however, to prevent the inlay from being forced out in this direction.

Instead of the anchorage illustrated in Fig. 40, that

shown in Fig. 43 may be used, if the pulp is sufficiently distant. Of these forms (Figs. 40—43), several may be employed in the retention of a single inlay. The presence of the anchorage Fig. 40 or 43 on one end is desirable; it acts as a guide in setting the inlay into the cavity.

From the above explanation, it becomes evident, that a complete box-shaped cavity is not always possibile, nor is it necessary for the retention of even a simple inlay. In certain places, however, where the inlay is exposed to the force of mastication, the complete form, with four walls, should be used. This refers especially to inlays on abraded surfaces. In preparing such cavities the following fact should always be remembered. *Two walls, opposite each other, and lying parallel to the direction of removal of the inlay, are of far greater value than four walls lying obliquely to this direction.*

The application of the box-shape to complex cavities of molars and bicuspids has occasioned much adverse criticism. For this exaggerated type of cavity, there are neither practical nor mechanical reasons, and its acceptance as the correct cavity-form for metal-inlays, has caused many operators to question the value of this method of filling teeth. In simple cavities the box-shape is employed to give the inlay a certain amount of mechanical anchorage in the tooth. In complex cavities, however, there are so many other forms of anchorage to select from, that, in the opinion of the writer, an exact box-shaped preparation becomes quite unnecessary.

Many authors have advocated making the cement layer between inlay and tooth in the depth of the cavity, as thin as possible, believing that under such conditions cement would be less liable to fail as a retentive agent. The fact however remains, that any force exerted upon the inlay is transmitted to the tooth through the cement layer, and that the force which a self-retentive inlay can resist is dependent upon the crushing-strength of the cement. Not the thickness of the layer, but the quality of the cement, is the determining factor, as can be seen from the following test.

Into the rough-walled chamber of the metal block B (Fig. 44), a roughened metal plug Z is set with cement, and

the parts suspended as shown in the diagram. By gradually increasing the weight on the scale-pan, the exact tension necessary to cause a failure of the cement layer is determined. If in a subsequent test, the block is made of cement instead of metal, the plug occupying the exact relative position as in the previous test, the weight supported will be the same or even greater. If instead of tension, pressure is applied to the plug, the tests with the metal and the cement block will

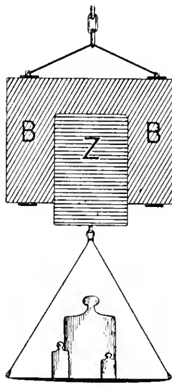

Fig. 44.

give the same result. The force necessary will however be much greater, as the crushing strength of cement is about ten times that of its tensile strength. The conclusions to be drawn from these experiments are, that a thin cement layer offers no advantage, and that the box-shape of a cavity, except at the margin, may be produced by cement. Practically this is of importance in cavity-preparation, as it often prevents the sacrifice of healthy tooth substance. The above tests emphasize a point to which attention has been called in Chap. III, that is, in using cement as a retentive agent the undercuts should be so placed and of such shape, that the crushing strength and not the tensile strength of the cement is relied upon.

As a result of making the cavities box-shaped and the cement layer as thin as possible, the inlay itself became box-shaped.

A careful consideration of Fig. 45 will show that the direction of the walls in the *depth* of the cavity, has no influence upon the retention of a *box-shaped inlay*, as soon as the intervening space is filled with cement. Far different, however, will be the result, if in a *box-shaped cavity* the direction of the lateral walls of the inlay are altered (Fig. 46).

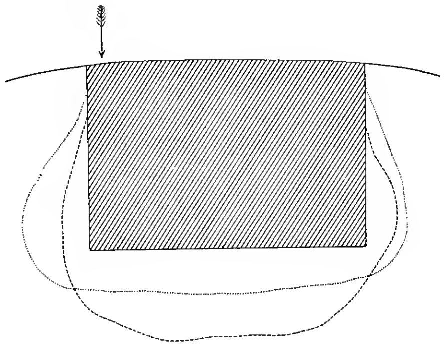

Fig. 45.

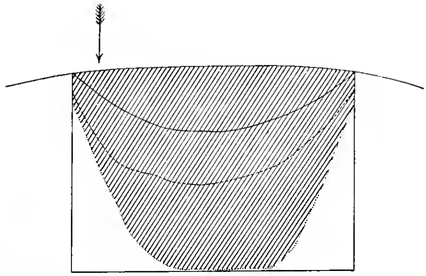

Fig. 46.

The greater the inclination of these surfaces, the more unfavorable will be the conditions for retention by means of cement (see Figs. 33—35). The good results which the box-shaped cavity preparation has shown, depend, in the opinion of the writer, less upon the form of the cavity, than upon the box-shape of the inlay.

Equally applicable, is this principle to the complex cavities of the molars and bicuspids. In the case of simple cavities it has been shown, that the superiority of the box-shaped

inlay depends upon the presence of at least *two surfaces lying on opposite sides of the inlay, and being parallel to the direction in which the inlay may be removed from the cavity.* By applying this simple rule to the most complex cavities of the molars and bicuspids, perfect retention can be readily obtained, and the unnecessary removal of healthy tooth-structure avoided. In describing the application of this principle to such cavitives, a lower molar with an occluso-proximal cavity has been chosen as an example. The retention is to be obtained by means of fissure-anchorage. Fig. 48 shows a section through tooth and inlay, Fig. 49 shows the form of the inlay on the occusal surface. For convenience of explanation the longitudinal fissure has not been completely filled. In practice this should never be omitted.

Mention has been made of the fact, that a proximal inlay extending to the occlusal surface, must be able to resist pressure in two directions, vertically and obliquely. The first is produced by the closure of the jaws and tends to force the inlay out of the cavity in the direction of the neck of the tooth; the second, produced by masticatory movements, tends to pry out the inlay in the direction of the interproximal space.

To give an inlay resistance to vertical pressure, the authors in whose opinion the box-shaped cavity preparation should be strictly carried out, advocate making as many surfaces as possible at right angles to the direction of pressure (Figs. 47 and 66). This in itself is perfectly correct. It gives the inlay a secure base; and in transmitting the force from the inlay to the tooth it puts the cement layer under compression, and not, as in the molar of Fig. 57, under tension. But it is questionable whether the practive of giving an inlay such an unnecessarily great power of resistance to vertical pressure is justifiable, if this is done by the removing large quantities of healthy tooth structure.

Fig. 17 shows how vertical pressure may dislodge an inlay resting upon a narrow cavity floor. In Fig. 18, to avoid this danger, the floor of the cavity has been broadened, i. e., a larger surface lying at right angles to the direction of pressure has

been produced. It is, however, not necessary, nor in larger cavities advisable, to place the whole of this bearing surface upon the gingival wall of a proximal cavity. A more favorable distribution of these surfaces will be discussed later. Strict box-shaped cavity preparation demands, that the floor of a proximal cavity be prepared in the form of steps. This besides being difficult and tedious, requires the unnecessary destruction of tooth substance.

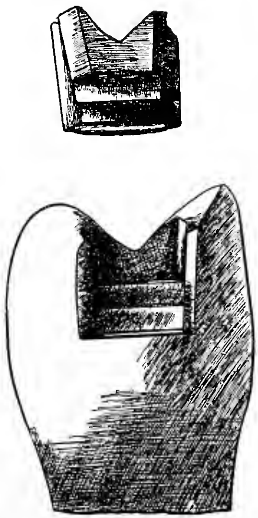

Fig. 47. (From a dental journal.)

Inclined grooves (Fig. 21) increase the bearing surface of the inlay. As in this case the inlay, under pressure, acts as a wedge, the lateral walls of the cavity must be very strong. To some extent this pressure may be relieved by giving the inlay a broad bearing surface upon the gingival wall of the cavity. It is however advisable to confine the use of this method of giving inlays the power of resisting vertical pressure, to the smaller proximal cavitities.

There remains another method by which the bearing surface of an inlay may be increased, and that is the fissure anchorage. This method has several advantages.

1. By cutting out the fissure, the surface effective in resisting vertical pressure is increased.
2. As this is done upon the grinding surface, the preparation is easier, quicker, and less painful than cutting steps or broadening the wall of the cavity at the neck of the tooth.

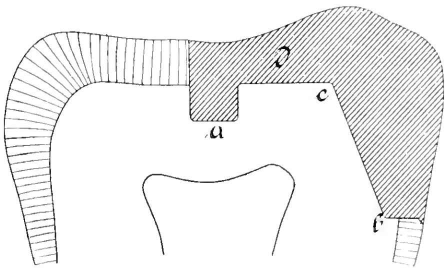

Fig. 48.

3. By filling the fissures, caries will be prevented.
4. By means of a specially prepared pit in the fissure (*a*, Fig. 48) or by an extension in the transverse fissure (*e*, *e*, Fig. 49), the inlay gains additional resistance to

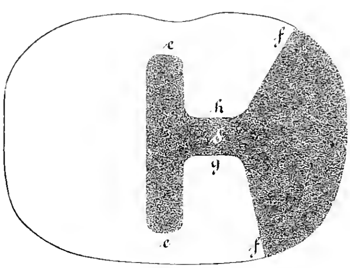

Fig. 49.

vertical pressure. Only by fracturing the tooth in the direction *a*—*b* (Fig. 48) or *e*—*f* (Fig. 49), can vertical pressure dislodge the inlay. The amount of pressure which an inlay of this form can resist, is dependent upon the depth of the pit *a*; the length of the extension *e*—*e*; the strength of the connection *d*, lying in the longitudinal fissure; and upon the strength of the tooth-struc-

ture between the points a and b, or e and f. The area of the floor of the proximal cavity is of but little consequence in this method of retention. As a result, the wall b—a (Fig. 48) need not be vertical, as in true box-shaped cavity preparation, thereby preserving a thicker layer of dentine over the horns of the pulp without decreasing the resistance of the inlay to vertical pressure. Special attention must be called to the fact that in this method of cavity preparation, the depth of the pit a, or the length of the extention e—e, and the strength of the connection d, should stand in direct ratio to the length and inclination of the wall b c.

5. Beside the above mentioned advantages, this form of inlay offers the most secure anchorage against the oblique pressure caused by the movements of mastication.

In the previous chapter the different forms of anchorage, designed to resist oblique pressure, were described. It is, however, necessary to explain the application of the principle — *walls parallel to the direction of removal of the inlay,* — to this class of retention. Fig. 18 shows the manner in which an inlay is tipped out of the cavity by oblique pressure. It has been mentioned that this may be prevented by the fissure-anchorage. If the cavity has been prepared in the manner shown in Fig. 50, the inlay will be able to successfully resist the *vertical* pressure. If oblique pressure be brought to bear on the point a, Fig. 51, the inlay will be tipped out of the cavity. Pressure exerted upon the proximal surface (Fig. 52), by hard particles of food wedging against the neighbouring tooth, or by forcing a tooth-pick into the interproximal space, may cause a dislocation of the inlay. In this form, the fissure-anchorage does not meet the requirements of the case.

The inlay must be so constructed that it can be *removed from the cavity in but one direction.* Preferably this direction is to be so chosen, that it is opposed to that of the vertical pressure. In order that an inlay may be guided in but one direction during its removal from the cavity, it must possess two surfaces which are opposite each other and parallel to the

direction of removal of the inlay. Fig. 53 shows that these parallel surfaces may be situated at *a* and *b*, *b* and *c*, or on the same inlay at *a*, *b*, and *c*. An inlay of this form can be dislodged

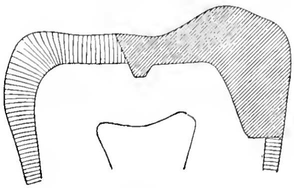

Fig. 50.

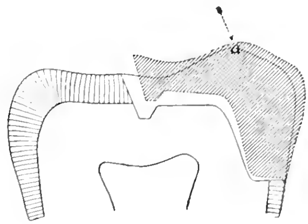

Fig. 51.

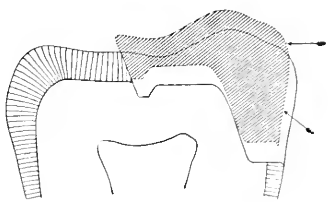

Fig. 52.

neither by vertical nor by oblique pressure, as the parallel walls form a guide which allows the inlay to be removed only in the direction of the arrow. The presence of these

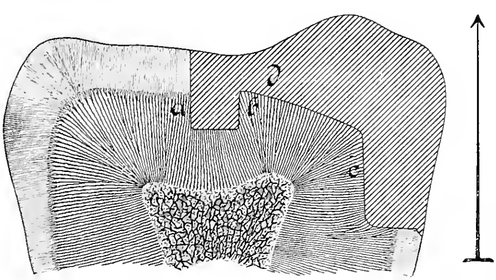

Fig. 53.

guide-surfaces is essential in every case, their size, however, in order to oppose the oblique pressure need not be large. This question will again be referred to in discussing the cement attachment of this class of inlays.

The office of the cement as a retentive agent for inlays in proximal cavities has not as yet been touched upon. Many inlays doing service for a long period of time in carefully prepared, but mechanically incorrectly shaped cavities, owe their retention entirely to the cement (Fig. 57). The same is true of some inlays in cavities prepared strictly according to the box-shaped principle (Fig. 66).

In certain proximal cavities of the posterior teeth, it is justifiable to disregard the mechanical anchorage, and to depend entirely upon the cement for retention. Such cavities, facing the space caused by an extraction, have their greatest diameter at the neck of the tooth, and involve but little of the occlusal surface (Fig. 54). To prepare the cavity so, that

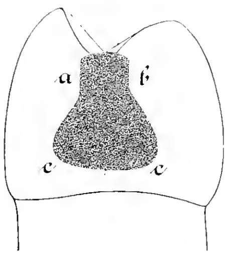

Fig. 54.

the impression could be removed only in the direction contrary to that of the vertical pressure, would be useless labor and an unnecessary destruction of tooth-substance. The practice of extension for prevention would not be indicated in this case, as there is no contact with an adjoining tooth.

If the impression is removed from the cavity in the direction of the space, the construction of a self-retentive inlay becomes impossible. It is therefore upon the cement that complete reliance must be placed. With a properly shaped inlay, this mode of retention may, however, be relied upon. The fact that the inlay possesses a small occlusal surface (Fig. 54), may be disregarded, and the cavity considered as a simple one, lying on the proximal surface of the tooth. It has been shown that sufficient retention can be given an inlay, by constructing two of its surfaces parallel to the direction of

removal. In the present case this direction would be toward the space, as the oblique pressure would tend to tip the inlay out of the cavity. In discussing mechanical anchorage it was shown, that to prevent dislocation, the hold should be applied as high as possible, that is, as far away from the fulcrum of the leverage as circumstances will permit (Fig. 21). The preparation of the parallel walls *a* and *b* (Fig. 54) is begun at the occlusal surface and continued as far as possible in the direction of the neck of the tooth, constantly keeping in mind that they are to be made parallel to the direction in which the inlay could be tipped out of the cavity. It is not necessary to make the walls parallel to the points *c*, as the chief hold lies at *a* and *b*. The gingival wall of the cavity should, however, be broad and horizontal, in order to oppose the vertical pressure.

Whether the inlay should be regularly undercut or simply roughened, must be decided from case to case. If the parallel surfaces *a* and *b* are small, or if the occlusal surface of the inlay is large, regular undercuts should be employed. If the contrary is the case, simple roughening will give ample security. As a rule, it is best to make short undercuts at *a* and *b*, lying at right angles to the direction in which the inlay can tip, and to employ the step-like roughening (Fig. 14) upon the remaining surfaces. Bevelling the occlusal surface toward the space, is to be recommended (Fig. 16); instead of being tipped out, the inlay is then pressed into the cavity more firmly by the vertical pressure.

The principles just described are applicable not only to the posterior teeth, but to proximal cavities of other teeth as well. Inlays constructed in this manner do very good service, but as a rule the anchorage of all larger inlays in the bicuspids and molars should depend upon self-retention.

The office of the cement, in retaining a correctly constructed, self-retentive inlay in the cavity, is confined to a filling out of all spaces between the inlay and the tooth, and to the prevention of dislodgement in the direction of removal. In discussing Fig. 53, it was stated that the parallel surfaces *a* and *b* need not be large in order to resist the oblique pressure.

For a reliable cement attachment, these surfaces alone are, however, too small. Only such surfaces which lie on sides opposite each other, and which are parallel to the direction of removal, are suitable for cement-retention. If no other surfaces of this description are present upon the inlay, the transverse fissure must be deepened considerably to increase the area of the surfaces *a* and *b* (Fig. 53).

In a cavity whose buccal and lingual walls are lacking (Fig. 49) and whose axial wall is inclined (*c*, *b*, Fig. 48), the parallel surfaces may be made upon the connecting segment of the inlay lying in the longitudinal fissure at *d* (Fig. 48

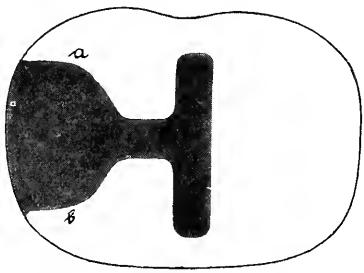

Fig. 55.

and 49). The depth of excavation necessary in the transverse fissure (*a*, Fig. 48 or *e*—*e*, Fig. 49) depends upon the area of the surfaces *g* and *h* (Fig. 49), and the inclination of the axial wall *c*—*b* (Fig. 48). If the parallel surfaces are small, regular undercuts are necessary at these points for reliable cement-retention (Fig. 10). As a rule however, roughening the surface of the inlay as shown in Fig. 14 is sufficient.

In case the lingual and buccal walls of the cavity have been preserved, the parallel surfaces on the inlay should be situated there. By virtue of the fact, that the inlay can be removed in but one direction, the proximal part may be considered as a simple cavity opening upon the occlusal surface. If then, the walls *a* and *b* (Fig. 55) are, for a short distance, made parallel to the direction of removal, ideal conditions for cement-retention will have been produced. If the axial wall is inclined, the surfaces *a* and *b* should be increased in

area. If the axial wall is vertical, and the walls *a* and *b* correctly prepared, deep excavation will become unnecessary in transverse fissure (*e—e*, Fig. 49).

Regular undercuts are not necessary in this class of inlays. That part of the inlay, lying in the fissure, is roughened by blows at right-angles to the surface (Fig. 13). The surface of the inlay, lying within the proximal cavity, is roughened

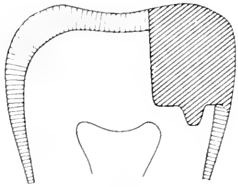

Fig. 56.

by an obliquely applied instrument (Fig. 14). As this throws up small projections, thereby slightly increasing the size of the inlay, a thin layer of dentine should be removed from

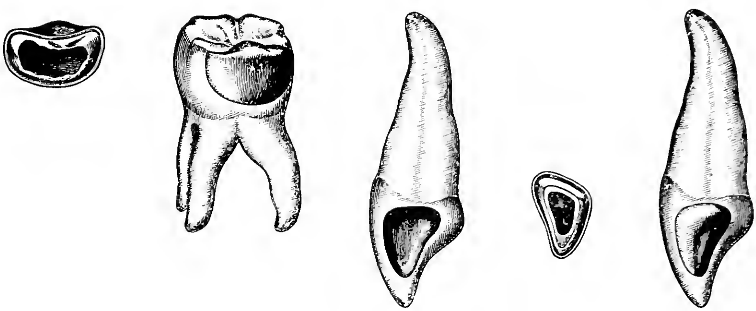

Fig. 57. (From a dental journal.)

the walls of the cavity at the points opposite to the surfaces so roughened.

In discussing the fundamental principles of retention, only certain cavities of the molars and bicuspids have been cited as examples, as these are the ones most commonly filled with metallic inlays. The application of the principles to other cavities is perfectly simple if the reader has understood the writer's ideas upon the subject of cement-retention and self-retentive inlays.

Before leaving this subject, a few examples of inlays with insufficient retention will be given. Fig. 56 shows a form of anchorage which has been repeatedly recommended. Without going into details, it is only necessary to call attention to the fact, that an inlay of this form cannot resist oblique pressure, as the hold it has on the tooth (the extension) is situated very close by to the fulcrum of the leaverage. Among the hollow inlays many examples of insufficient retention may be found (Fig. 57). In filling out the space, the cement gains a firm hold on the inlay; the hold upon the tooth, however, is entirely dependent upon the adhesive power of the cement. Granting the latter to be sufficiently strong, the retention of the inlay then depends upon the tensile strength of the cement, and this, as has been previously mentioned, is not very great.

Chapter V.

Caries and Cavity-Form.

Though this subject has been thoroughly discussed in text-books on operative dentistry, it is deemed advisable to emphasize certain points which should be considered in preparing cavities for metallic inlays. Experience has shown, that it is not necessary to remove any more, and sometimes even less, tooth-substance in preparing a cavity in which a metallic inlay is indicated, than in preparing the same cavity for a perfect gold foil filling. For comparison, the cavity preparation for foil fillings as advocated by G. V. Black*), has been chosen.

In preparing a cavity, the fact should never be overlooked, that the office of a perfect filling is not alone to restore the destroyed parts, but that it should also protect the tooth at that point from recurrent caries. For this reason, it has become a recognised practice in filling the fissures on the occlusal surfaces of the posterior teeth, to excavate the affected fissure throughout its whole length. To what extent this principle should be applied to the proximal cavities is a mooted question. Theoretically the practice is justifiable, practically, however, experience has proven that it is not always necessary.

The point of origin of dental caries is either a fissure, or a smooth surface protected from the cleansing action of mastication. The course of the carious process is dependent upon its point of origin. Caries in enamel, as well as in dentine, progresses in the form of a wedge. In caries of the fissures, the points of the wedges lie in opposite directions (*a*, Fig. 58). In the enamel the process is somewhat limited, while in the dentine, owing to the less resistant dentine-enamel margin, the spread of caries is far more rapid. The effected area of

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*) G. V. Black, Operative Dentistry, Vol. II.

the dentine is therefore considerably larger than that of the enamel.

In caries beginning upon smooth surfaces, the points of the affected wedge-shaped areas lie in the same direction

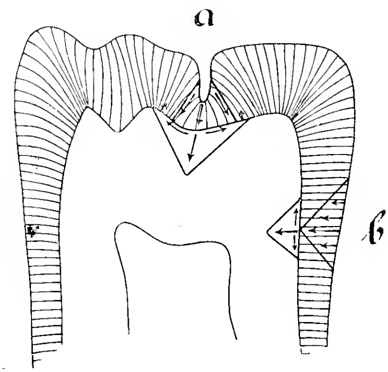

Fig. 58 (after Black).

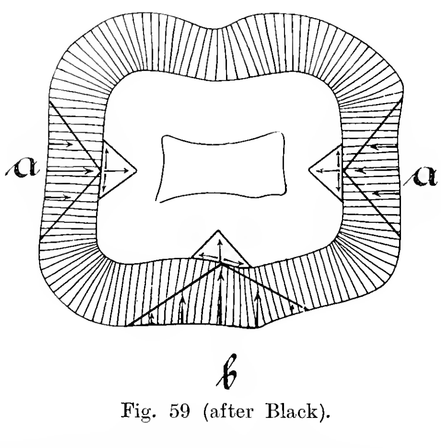

Fig. 59 (after Black).

(*b*, Fig. 58, *a* and *b*, Fig. 59). In contradistinction to caries of the fissures, the area of the enamel involved is larger than that of the dentine. This is explained by the fact, that the agents producing caries can more easily attack the surface of the enamel at more protected points than upon the self-cleansing occlusal surface of the teeth.

An examination of Fig. 58 proves, that a broad excavation

of the fissures is perfectly justified on account of the spread of the caries along the dentine-enamel margin. This is of advantage to the inlay, as thereby the extensions lying in the fissures are greatly strengthened, thus giving the inlay a firmer anchorage in the tooth.

The writer considers the box-shaped cavity, as usually recommended, not at all necessary for an inlay. It requires extra labor and a useless destruction of tooth substance, sometimes to such an extent as to endanger the horns of the pulp. A cavity prepared in the tooth Fig. 58, would fulfill all requirements, if it had the form shown in Fig. 60. The course of the enamel prisms is such that the cavity margin need not be bevelled. This gives the inlay two parallel surfaces lying

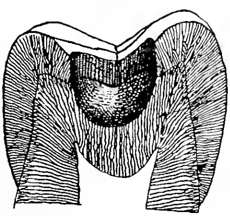

Fig. 60 (Black).

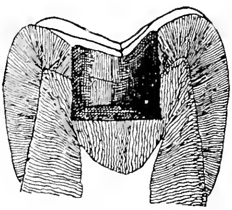

Fig. 61 (Black).

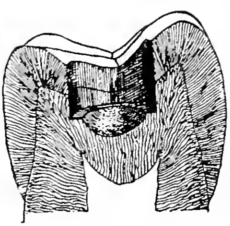

Fig. 62 (Black).

opposite eachother, which is amply sufficient for cement-retention. The impression can be more easily removed from this form, than from a box-shaped cavity.

If the cavity (Fig. 60) is to be filled with gold, the floor must be made flat. If this is done at right-angles to the deepest point, the form shown in Fig. 61 will result. This would probably endanger the horns of the pulp. To avoid this danger, Black advocates cutting a ledge a little above the deepest part of the cavity (Fig. 62). For an inlay this form of cavity offers no advantage over that of Fig. 60. Besides being a loss of time, cutting the ledge increases the danger of making undercuts in the walls of the cavity. It is just in the fissure cavities, where the amount of the material is small, that the slightest undercut may produce distortion during the removal of the impression.

The preparation of box-shaped cavities upon the smooth

surfaces, necessitates a still greater destruction of tooth-substance than is the case in fissure cavities. This becomes evident in examining cervical caries on the buccal surface of a lower molar. Caries at this point spreads in a horizontal direction (*b*, Fig. 59), while vertically it remains limited

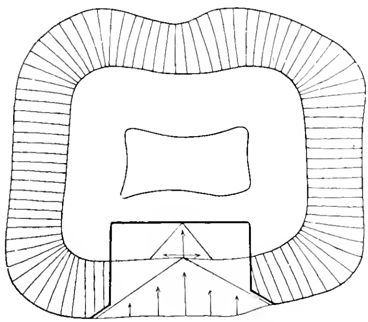

Fig. 63.

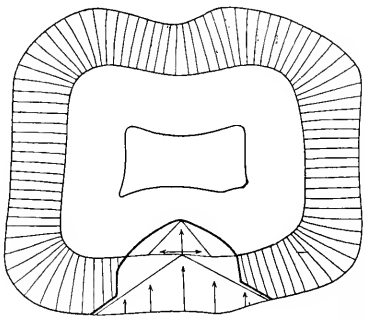

Fig. 64.

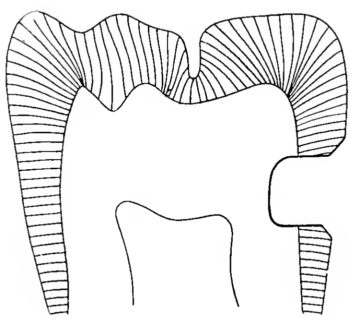

Fig. 65.

(*b*, Fig. 58). Instead of box-shaped (Fig. 63), such a cavity may, without endangering the retention, be prepared almost saucer-shaped in the horizontal direction (Fig. 64) as long as the vertical section shows two parallel walls, lying opposite each other (Fig. 65).

Proximal cavities prepared along similar lines, also show the same advantage. A box-shaped cavity cut into the tooth at *a* (Fig. 59), would require the removal of a considerable quantity of healthy dentine. By preparing such a cavity in

the manner described (Plate I), this needless destruction is obviated. A vertical section through the proximal cavity shows that it is necessary to remove less tooth-substance in preparing a cavity for a metallic inlay than in preparing the same cavity for a foil filling. The inlay has the following advantages: The gingival wall of the cavity need neither be large nor perfectly horizontal (Fig. 48); the cavity walls need not meet at sharp angles; and the axial wall need not be

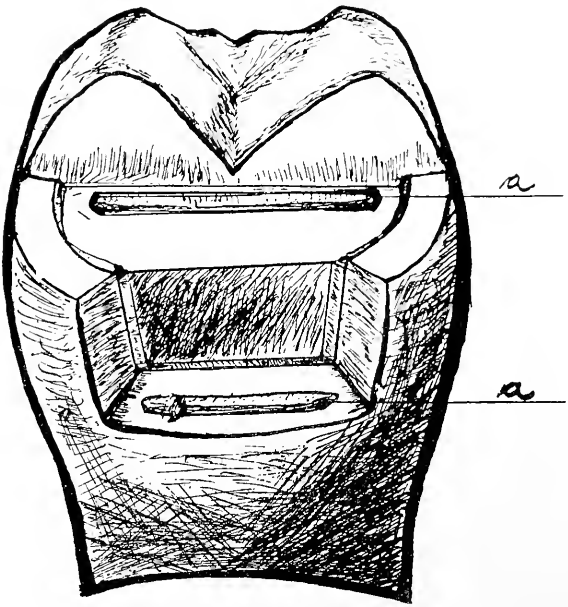

Fig. 66. (From a dental journal.)

vertical. These requirements not only denote a saving of tooth-substance, but they also make cavity preparation considerably less difficult.

To what extremes the advocates of strictly box-shaped cavity preparation have gone, is shown in Fig. 66. In the preparation of this cavity, intended for a bridge-abuttment, the vertical pressure to which the inlay is subjected, has almost exclusively been taken into account. The oblique pressure, caused by the movements of mastication, has received but little attention. Neither the grooves *a*, *a* (Fig. 66), nor

undercuts can give sufficient anchorage to prevent the leverage, which is especially great in a bridge-abuttment, from dislocating the inlay.

So far only those points, in which the cavity preparation for an inlay differs from that of a foil filling, have been mentioned. In other respects, the principles underlying the preparation of cavities for foil fillings and for metallic inlays are identical.

These principles will only be briefly mentioned in order to emphasize the fact, that a more extensive excavation is not necessary for an inlay than for a gold filling. Proximal cavities to be filled with inlays must be extended laterally, to allow the impression to be drawn. This procedure has been condemned as a useless sacrifice of healthy tooth-substance. If, however, the long experience of operators who have given this subject their special attention, counts for anything, then the extended cavity, inevitable to a certain extent in an inlay, represents the most perfect form for a foil-filling. This method of cavity preparation, the so-called "extension for prevention*)" of Black, is a prophylactic measure, pure and simple, and never should be regarded as anything else. The marked difference in opinion as to the value of this method, has bred extremists in each direction. It is, however, just as unreasonable to disregard it entirely, as to practice it in every case. Being a prophylactic measure, it should be practiced only when indicated.

The theory of extension for prevention**) is based upon the fact that caries but very rarely attacks surfaces cleansed by the food during the act of mastication. In normally placed teeth, the surfaces especially immune to caries are situated in the region of the mesio-lingual, the mesio-buccal, the disto-lingual and the disto-buccal angles, and extend from the neck to occlusal surfaces of the teeth (Fig. 67 and 68). For this reason, it is often advisable, as a prophylactic measure, to place the margin of the cavity in the region exposed to the cleansing action of the food.

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*) This term is here used in the most limited sense, and does not include the idea of contour or contact-point.

**) G. V. Black, Operative Dentisby.

The cleansing action of mastication is dependent upon the width and depth of the embrasures formed by the surfaces of adjoining teeth. If the embrasures are narrow, (Fig. 69),

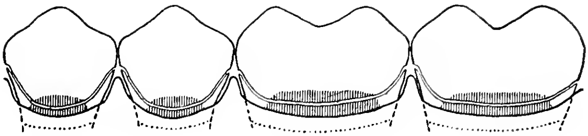

Fig. 67 (Black).

Shaded portions represent areas most liable to caries. The continuous black line represents the free margin of the gum, while the dotted lines show its attachment to the necks of the teeth. The double line shows the course of the saw in making the cross-section Fig. 68.

the food glides only over the lingual and the buccal surfaces of the teeth, if on the other hand, they are wide (Fig. 70)

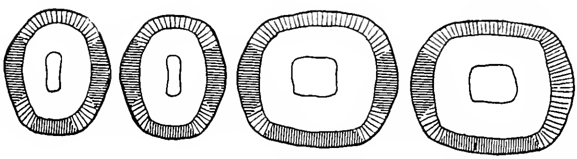

Fig. 68 (Black).

a greater part of the proximal surfaces are also cleansed. As the form of the embrasure is dependent upon the contour

Fig. 69 (Black).

Fig. 70 (Black).

of the tooth, it is necessary, in order to obtain a wide embrasure, to build out the filling or inlay, as far and as rounded as possible. Even though the natural tooth does not possess this rounded contour (Fig. 69), it should be present on the finished filling. As a rule there is not sufficient space for a contour filling,

and seperation must be resorted to. Guttapercha as a slower, and cotton with varnish as a more rapid method, give good results. For immediate seperation, the seperator must be used.

To forcibly produce a wide space at any point in the arch, in cases where the teeth stand very closely, is a procedure which the writer believes to be injurious to the other teeth. Secondary caries will probably be prevented at the place filled, but the increased pressure will make the proximal surfaces of the other teeth more liable to attack. To produce an inlay with a good contour in such an arch without taking up more space than the tooth originally occupied, the proximal surface should be ground flat with a diamond-disk (Plate V).

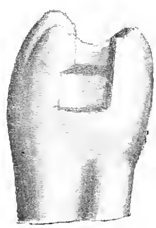

Fig. 71 (Black).

The margins of the cavity then lie in the region immune to caries, and there is sufficient space to give the inlay a good contour without still more crowding the arch. The best results are obtained by this procedure when two proximal cavities, lying opposite one another, are to be filled at the same time.

With inlays, the form of the interproximal space and that of the cervical margin should be the same as with gold fillings. The cervical margin should lie well toward the margin of the gum; should be horizontal; and not too short in the linguo-buccal direction. It is not, however, necessary to make the lingual and the buccal angles as sharp as is recommended for gold fillings (Compare Plate I and Fig. 71). To obtain sharp angles, burs or chisels must be used, and these are very liable to produce undercuts. With stones of proper shape and size, the proper cavity-form is produced almost automatically.

The shape of the interproximal space is determined by the distance between the teeth and the position of the contact point. The latter should form a decided eminence (Fig. 72), and not be gently rounded as in Fig. 73. The contact point should lie just above the junction of the upper and middle thirds of the crown of the tooth (Fig. 72). The inlay should

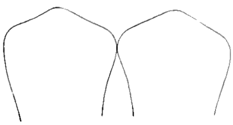

Fig. 72.

Fig. 73.

Fig. 74.

be as flat as possible below the contact point, as in Fig. 72, not as in Fig. 73 or 74, so that the "pumplike action" of mastication can readily keep the interproximal space clear.

A careful consideration of the facts discussed in this chapter, will disprove the assertion, that the inlay requires an unnecessary sacrifice of tooth-structure, if the theory of extension for prevention is accepted and exaggerated box-shaped cavities are avoided.

Chapter VI.

The Enamel Margin.

Of prime importance for the durability of an inlay, is the correct preparation of the enamel margin of the cavity. This margin should be so prepared, that it possesses the greatest possible resistance to injury under the following circumstances:

1. During the time that the cavity is temporarily filled, that is, between the time of taking the impression and of setting the inlay.
2. During the process of fitting and burnishing the inlay.
3. When the cement has been slightly dissolved out of the seam.
4. In reclosing the seam by burnishing the gold against the enamel margin.

Simply bevelling the edge does not, in all cases, insure against failure. It is the structure of the enamel, that is, the course of the prisms, that must be taken into account. As has been mentioned, the surface of the cement is dissolved to a depth equal to the width of the seam. The right-angled enamel edge, no longer supported by the cement, is very liable to fracture. To prevent this, bevelling the edge 30 to 45 ° has been advocated. If the enamel were a body equally resistant in all directions, this precaution would suffice. The fact, however, is that enamel is easily cleavable parallel to the course of the prisms. If in preparing the margin, the direction of the prisms is not accurately noted, a failure will result in certain places on the teeth in spite of the fact that the enamel edge was carefully bevelled. Fig. 75 shows a section through the margin of a cavity filled with an inlay. The enamel has been bevelled as advocated. The prisms, however, lie, as they do in various places on the teeth, very obliquely to the surface. As long as the cement within the seam remains

intact, the enamel cannot fracture, when in time the cement is dissolved, the oblique prisms loose their support, and are soon broken away. The seam is thereby widened, allowing a further solution of the cement to take place. When the dissolution of the cement has reached the point *a* (Fig. 75), a part of the enamel, of the form *b*—*a*, will gradually crumble away. If the course of the prisms is at right angles to the surface and the enamel edge slightly bevelled (Fig. 76), the danger of fracture is reduced to a minimum. It is therefore

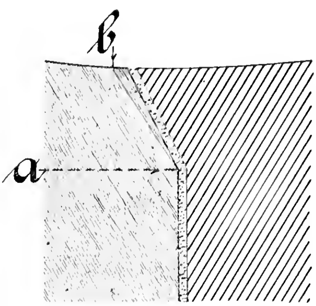

Fig. 75.

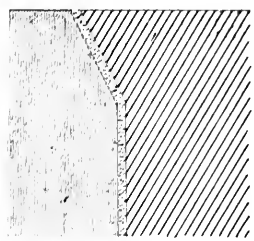

Fig. 76.

evident that the most favorable position for the cavity wall in the enamel region, is parallel to the direction of the prisms. This may, or may not result in a cavity wall lying at right-angles to the surface of the tooth.

The operator can only prepare cavities correctly, if he has a thorough knowledge of the course of the prisms on the surfaces of each individual tooth. A study of the Figs. 77—82 shows that as a rule the prisms lie at right-angles to the surface. Exceptions are found on the occlusal surfaces and adjacent thirds of the crowns of the molars and bicuspids. The enamel prisms of the incisors, particularly on the lingual surface (Fig. 77), lie very obliquely. In preparing a cavity on this surface, the wall toward the incisive edge, must be especially oblique in the region of the enamel. The mesial, and more markedly the distal angles of the cutting edge of the incisors, show an oblique position of the enamel prisms (Fig. 78), especially in the upper lateral incisor. In a cross section through

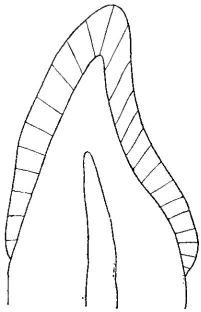

Fig. 77 (Black).
An axio-labio-lingual section of an incisor.

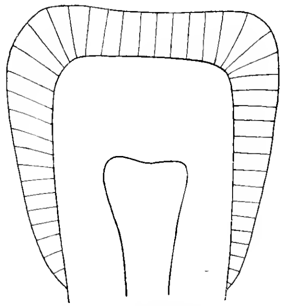

Fig. 78 (after Black).
An axio-mesio-distal section of a lateral incisor.

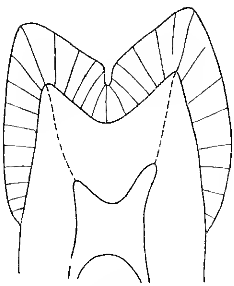

Fig. 79 (Black).
"A bicuspid tooth split bucco - lingually showing the directions of the enamel rods in the different parts of the plane of the cut. The recessional lines of the horns of the pulp are shown by the dotted lines."

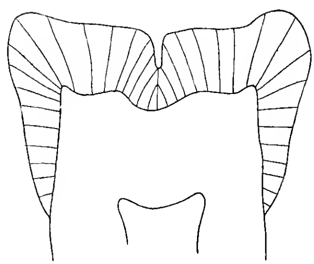

Fig. 80 (Black).
"A mesio-distal section of a lower molar tooth showing the more usual directions of the enamel rods in the different parts of the plane of the section."

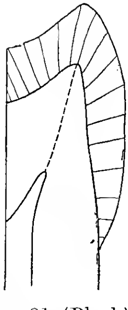

Fig. 81 (Black).
Perpendicular section through the cusp of a molar thooth.

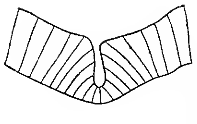

Fig. 82 (Black).
Section across a deep fissure.

the middle of an incisor, the course of the prisms is at right-angles to the surface, except at the mesio-lingual and disto-lingual angle. Again in the upper lateral incisor this condition is most marked. In the cuspids, the course of the prisms is at right-angles, except upon the lingual surface, where they lie similar to those of the incisors at this point.

In the molars and bicuspids the prisms lie at right-angles to the surface, expect in the regions about the cusps and the fissures. From the diagrams taken from the latest work of Black*), it appears, that in preparing a cavity on the occlusal surface but little bevelling of the margin is necessary to prevent cleavage of the enamel. The most favorable conditions are found in the neighborhood of deep fissures (Fig. 82). In such cases bevelling the edge becomes quite unnecessary.

These diagrams show the normal course of the prisms at various points upon the teeth; in practice abnormal conditions are, however, often encountered. During the preparation of the cavity, the direction of cleavage can easily be determined, if necessary, by fracturing the edge of the enamel with a sharp chisel and noting the direction of the break.

Not the surface of the tooth, but the course of the prisms determines the angle of the cavity wall within the enamel region. The cavity wall should be parallel to the prisms or cross their outer ends. Never under any circumstances should the inner or dentinal end of an enamel prism be needlessly cut. This, not alone for mechanical, but also for physiological reasons.

Morphologically the enamel may be divided into two zones, an outer, in which the prisms lie parallel to eachother and generally at right-angles to the surface, and an inner in which the course of the prisms is very irregular (Figs. 84 and 83). Cleavage of the outer zone takes place easily, of the inner zone only with great difficulty. Usually the inner zone is by far the broader of the two. This is of interest in connection with cavity preparation as it proves the danger of fracture to be greater near the surface of the enamel.

*) G. V. Black, Operative Dentistry, Vol. II.

Fig. 84 shows that it is not possible to cut a cavity wall, parallel throughout to the course of an enamel prism. The theoretically correct preparation of the cavity wall within the

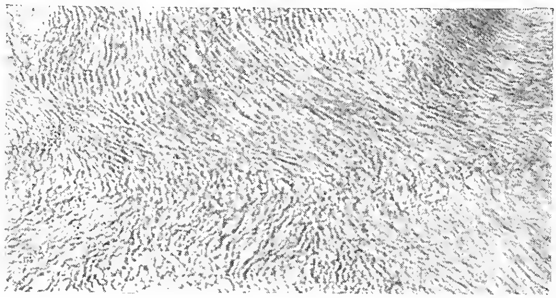

Fig. 83.

enamal region is the following: in the inner two-thirds of the enamel the wall should lie parallel to the direction of cleavage,

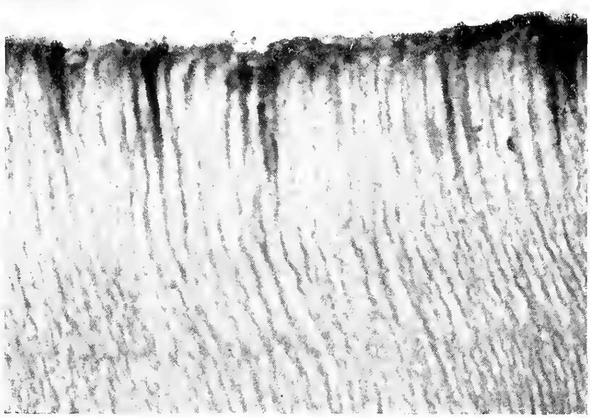

Fig. 84.

while in the outer third, it should be bevelled slightly. In practice, however, this rule can but rarely be observed, as abutting joints should be avoided on account of the contraction of the gold. Upon the occlusal surface the diffi-

culty may be overcome by carving deep fissures in the inlay (wax model). The edge of the inlay will then no louger be right-angled, but be so thin that it may easily be burnished against the margin of the enamel. Upon the other surfaces of the teeth the enamel margins should be bevelled about 45°, unless the inlay already possesses a thin edge.

Chapter VII.

Instruments for Cavity Preparation.

A description of all the instruments required for the preparation of cavities is not necessary. Only those which are of special value in inlay technic will be considered.

In preparing a cavity for an inlay, the possibility of removing the impression must always be kept in mind. On account of the danger of undercuts the use of small burs or of instruments of unsuitable form, should always be avoided. Almost all cavities can be prepared completely by the aid of stones. Carborundum stones cut rapidly, leave smooth margins, and if kept moistened are more agreeable to the patient than steel burs. The forms most commonly used are the barrel-shaped, ground somewhat conical upon a file, the spherical and the thin wheel.

In order to suit individual requirements, it is advisable for each operator to mount his own barrel-shaped stones. If the mandril possesses a thread, this should by ground off at two points opposite another, in order to prevent the stone from unscrewing when used with the engine reserved. The stones are mounted with thinly mixed cement. A number may be mounted at the same time as they must all be trued later. After the cement has hardened the mandril is mounted in a lathe, and the stone trued up with a file, and any desired special form produced. If no lathe is handy, the stones may be trued under moisture, on the engine. Care should be taken that no water mixed with carborundum is drawn up into the hand-piece. Before grinding, the mandril should be well covered with vaseline. Dry grinding is equally dangerous, as the carborundum dust rapidly wears out the hand-piece. Instead of a file, the instrument shown in Fig. 84 a, may be used. The stone is cut by an adjustable diamond point.

Barrel shaped stones can be obtained in several sizes. The most practical is about $^1/_4$ inch long and of about the same diameter (Fig. 85). With a file, the stone is formed as shown in Fig. 86. Wear constantly decreases the diameter of the

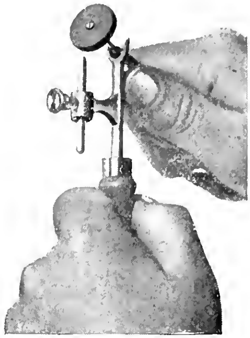

Fig. 84a.

stones, making the preparation of stones of different sizes unnecessary. If the tip, in time becomes too pointed, it should be squared with a carborundum wheel (Fig. 87). Small zylindrical stones, in shape similar to large fissure burs, and sold

Fig. 85.

Fig. 86.

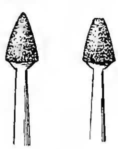

Fig. 87.

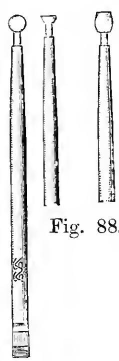

Fig. 88.

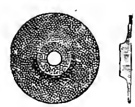

Fig. 89.

under the name of Miller's points (Chicago), are often of service. Small round stones, about an $^1/_8$ inch in diameter are indispensible for finishing the cervical enamel margin. Different sizes result through wear. The other forms of these points (Fig. 88) may sometimes be required. The small car-

borundum disk (Fig. 89), as well as the stone shown in Fig. 116, is used to cut out the fissures on the occlusal surface, and to prepare cavities for the dove-tail or the hook anchorage.

If the smallest diameter of a cavity is less than an $^1/_8$ inch, stones cannot be used. The cavity must then be prepared with burs, and the margins finished with plug finishing burs, or in a manner to be described later.

As a substitute for small stones, instruments impregnated with diamond dust have been put upon the market. Owing to their high price and their rapid deterioration, they have not come into general use. Instruments made of copper and used with carborundum powder are more satisfactory. It will be found, however, that aluminum cuts still better. Small disks cut out of aluminum plate, are mounted on a mandril and trued on the engine. A cylindrical form is made by cementing a short piece of small, thick-walled aluminum tubing upon an old bur, and trueing as described above. As a cutting medium, coarse carborundum powder, mixed to a stiff mass with low-melting paraffin, can be recommended. In grinding it becomes less fluid than vaseline and is therefore not thrown off of the disk as easily. A small piece of the mass is placed in the cavity. The heat generated in cutting sufficiently liquifies the paraffin to insure a constant supply of carborundum powder at the cutting edge. If the mass is too hard, the instrument should first be dipped into vaseline. During the operation, it is advisable to cool the tooth with air. In cutting with abrasive powders, pressure should never be applied to the instrument.

Cavities cut by this process have extremly smooth walls and almost knife-edged margins. It will never be generally adopted, however, unless diamond-dust, real or artificial, can be produced so cheaply as to replace the carborundum powder. In that case it would be a most rapid and painless method of excavating cavities. The great disadvantage in its present form is, that in comparison to the cutting speed of carborundum stones and steel burs, it is very slow. In small cavities, prepared with burs, a very smooth enamel margin can be obtained

more rapidly with carborundum-powder and aluminum than with arkansas-stones.

The right-angle hand-piece is indispensable in the preparation of cavities for inlays. In other methods of filling,

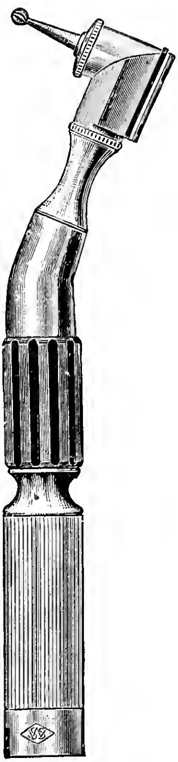

Fig. 90.

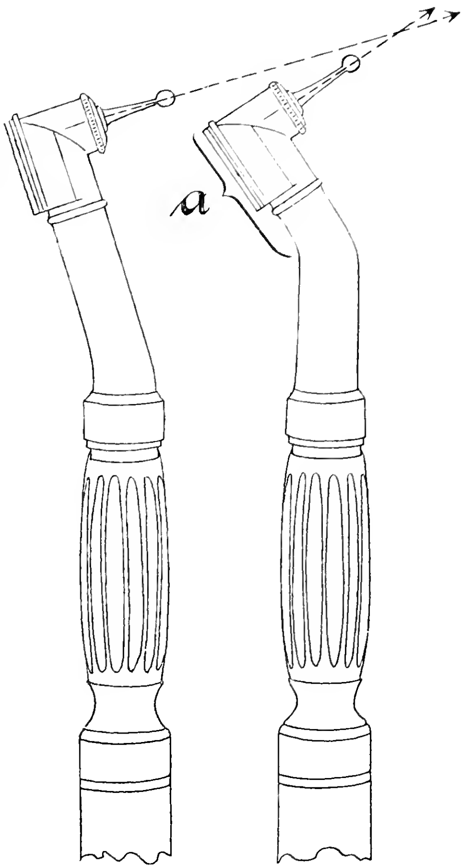

Fig. 91.

the cavities can be prepared with the straight hand-piece. The inlay, however, requires a cavity perfectly free from undercuts, and this can be produced only by working in the direction in which the impression is to be removed from the cavity. The cutting instrument must therefore in each case occupy

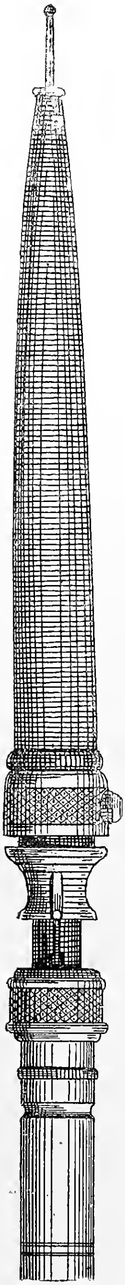

Fig. 92.

a certain definite position. This can be accomplished, as a rule, only by the use of the right-angle hand-piece.

The general prejudice against this instrument is the result of the incorrect form of most right-angle hand-pieces. Usually the head of the bur lies far from the axis of the hand-piece, thus making accurate work impossible. In the contra-angle (Fig. 90) this deficiency has been remedied to a great extent. The head of the bur lies about in the axis of the hand-piece, thereby giving the operator almost the same control over the cutting instrument as in a straight hand-piece. Even in the contra-angle the tips of the long cylindrical stones do not lie quite in the axis. This is rarely disturbing unless the stones are too long.

In selecting a right-angle for inlay cavity preparation, it must be ascertained that the head of the ordinary bur lies in the axis of the hand-piece, and that the distance from the angle of the shank to the head is sufficiently long. If this distance is too short (Fig. **91**, *a*) the angle in the shank must be more acute in order to bring the head of the bur into the axis of the hand-piece. This places the axis of the bur in an unfavorable position; considerably less than at a right-angle to the axis of the hand-piece. As the cutting instrument must always be applied at right-angles to the surface of the tooth, a hand-piece of this form is almost useless in preparing cavities for inlays in the posterior teeth.

The use of stones causes the hand-pieces to wear out very quickly, owing to water mixed with carborundum being drawn up along the mandril. The right-angle suffers most in this respect. The straight hand-piece can be protected from this injury, which is especially marked in working upon the upper teeth, by using Kiefer's aseptic rubber

sheaths (Fig. 92). The mandril should be coated with vaseline before introduction into the hand-piece. Though making a moisture-proof joint, the objection to the use of these sheaths is the difficulty of stretching them over the hand-piece. As, for reasons of asepsis, a fresh sheath should be used for each patient, their use entails considerable trouble. If a small rubber cap of this style could be made, to easily slip over the head of the right-angle, it would greatly prolong the usefulness of this hand-piece. The instruments necessary in finishing and polishing the inlay, will be described in a later chapter.

Chapter VIII.

Cavity Preparation.

A description of each and every cavity which could be filled with an inlay, would be of little use to any one not acquainted with the fundamental principles of the cavity-forms for inlays (Chap. III and IV). The operator who fully understands these principles has no need to follow a description or an illustration in preparing a cavity. He is able to decide in each case, what form of cavity, and which anchorage is most suitable. The description of cavities will therefore be limited to those generally filled with inlays, and the chief points to be considered in the preparation, will be only briefly mentioned.

As a rule the cavity must be opened with chisels or burs, before stones can be used. When the opening is sufficiently large a stone of suitable form is employed. Care should be exercised in the selection of the stone, as with one of proper shape the correct cavity-form is cut almost automatically. Leathery dentine must first be removed with excavators, as stones cut it but slowly.

The cavity is prepared until it presents a margin of healthy dentine and enamel. Carious spots, not near the margin are removed after the impression has been taken. It sometimes occurs, that the general form and the margin are satisfactory while there still are undercuts in the walls of the cavity. In such cases the latter should be filled with Fletcher's Artificial Dentine, and the cavity again ground out with stones of suitable form.

Where there is danger of injuring the neighboring tooth, stones of small diameter should be used. If contact is unavoidable, placing a piece of a thin seperating file in the

interproximal space, is to be recommended. When worn through a new piece is substituted. This precaution is, however, rarely necessary.

The following plates are reproductions of cavities cut into enlarged plaster models of teeth. In the mouth where the conditions, especially in regard to accessibility, are not so favorable, it is not always possible to prepare the cavities so exactly. This is true particularly of the enamel margin.

Plate I.

Lower Molar with Mesio-Occlusal Cavity.

The proximal cavity should be broad, and be prepared with care in the region of the pulpal horns. These points of danger lie upon a line drawn from the tips of the cusps to the pulp-chamber (Fig. 81). Between the pulpal horns, the cavity has been deepened, to make the segment (*d*, Figs. **49** and 53) as strong as possible. The enamel margin is to be bevelled as described.

On the occlusal surface, the fissures have been cut out with a carborundum disk. The sharp angles produced at the crossing of the fissures have been rounded. If the excavated fissure extends to the edge of the occlusal surface, the margin of the enamel should be ground away horizontally. (On plate I, the left end of the transverse fissure.) At other points of the occlusal cavity, bevelling the enamel margins is not necessary if deep fissures are carved in the inlay.

Plate I.

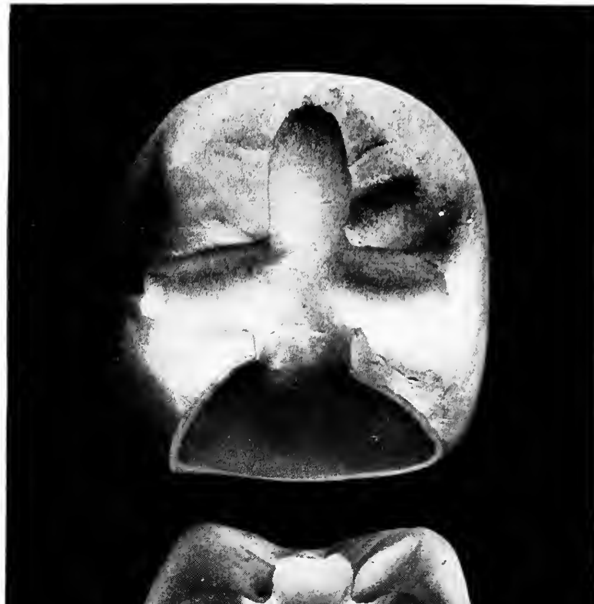

Plate II.

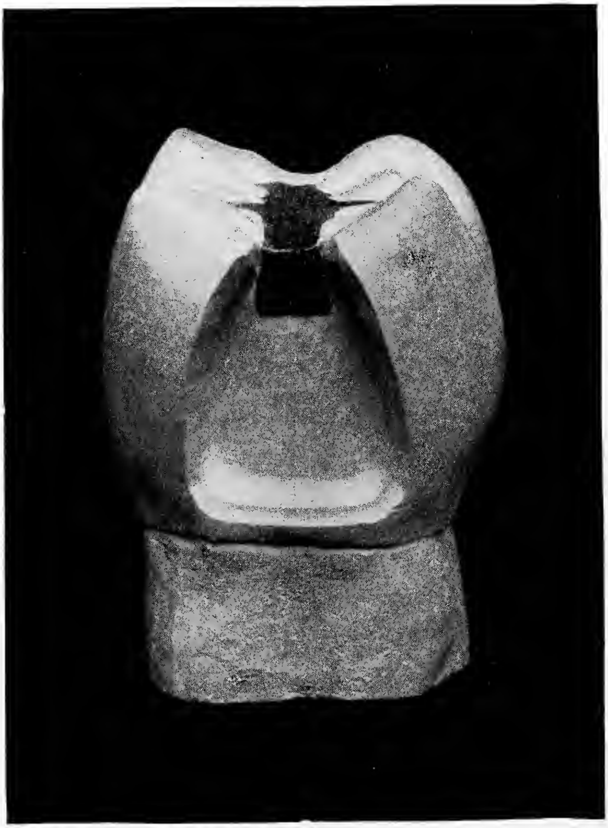

Plate II.

Lower Molar with Disto-Proximal Cavity. Adjoining Tooth Missing.

The presence of a filling upon the occlusal surface is assumed. The adjoining tooth being absent and the occlusal surface but slightly involved, the inlay may be made without self-retention. The greater part of the proximal surface being carious, the cavity could not be prepared like Fig. 54. Sufficient retention has been obtained by cutting all the walls, at right-angles to the proximal surface. The enamel margins have been bevelled. On the inlay, the small occlusal surface should be sloped proximally (Fig. 16).

Plate III.

Lower Molar with Lingual Wall Missing.

To seat the inlay more firmly, the gutta-percha filling the pulp-chamber has been partially removed, and the remaining portion of the lingual wall ground off horizontally. The enamel margins have been bevelled, with the exception of those of the dove-tail anchorage cavity. For the preparation of the latter see Figs. 27 and 28.

Plate III.

Plate IV.

Plate IV.

Lower Molar with Abraded Occlusal Surface.

The cavity should be made as broad and deep as possible; the walls cut vertically and their upper edges rounded. To give greater security against dislocation, the grooves instead of being cut obliquely, may extend entirely through the walls of the cavity. If necessary, the pin anchorage (Fig. 32) may be used. The enamel margins are to be broadly bevelled.

Plate V.

Lower Bicuspid in a Crowded Arch, with Mesio-Occlusal Cavity.

The mesial surface of the tooth has been flattened with a diamond disk. The margin of the enamel in this case should not be bevelled. Retention is obtained by means of a strong fissure anchorage, or if preferred by cutting a dove-tail in the distal part of the occlusal surface. (See page 60.)

Plate V.

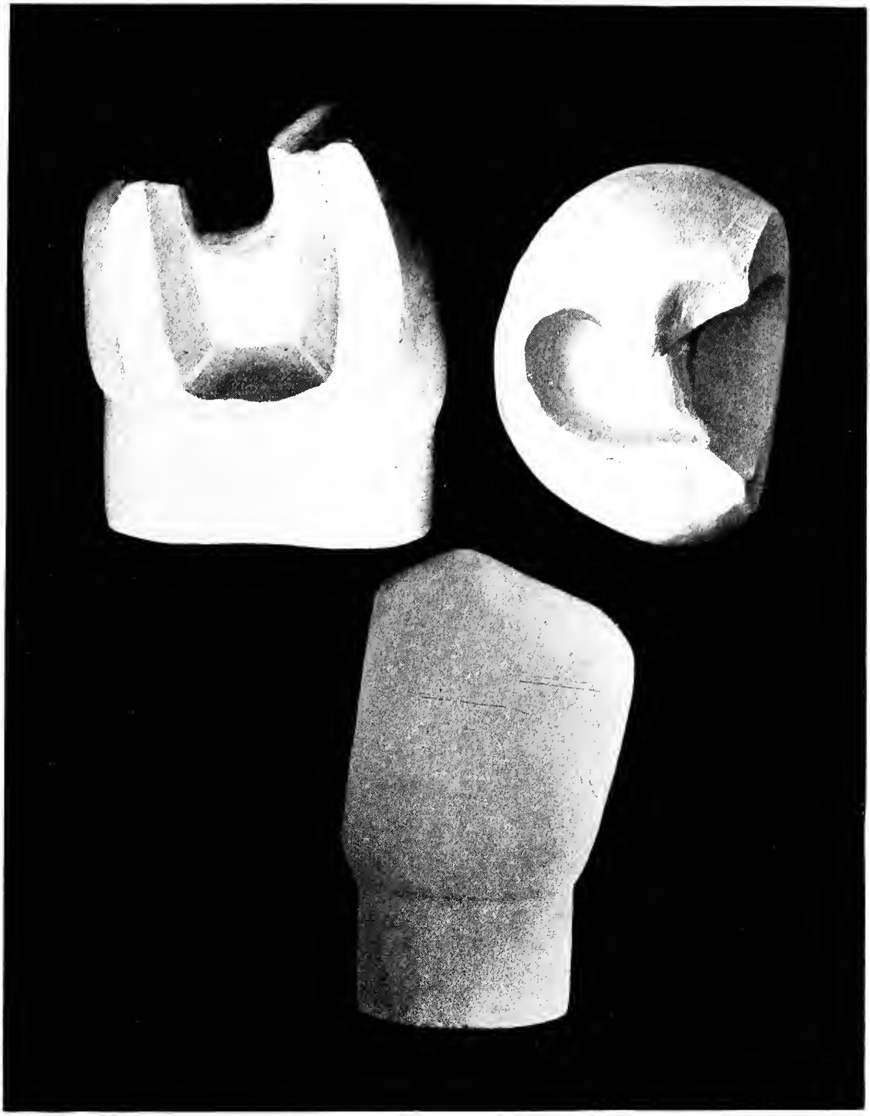

Plate VI.

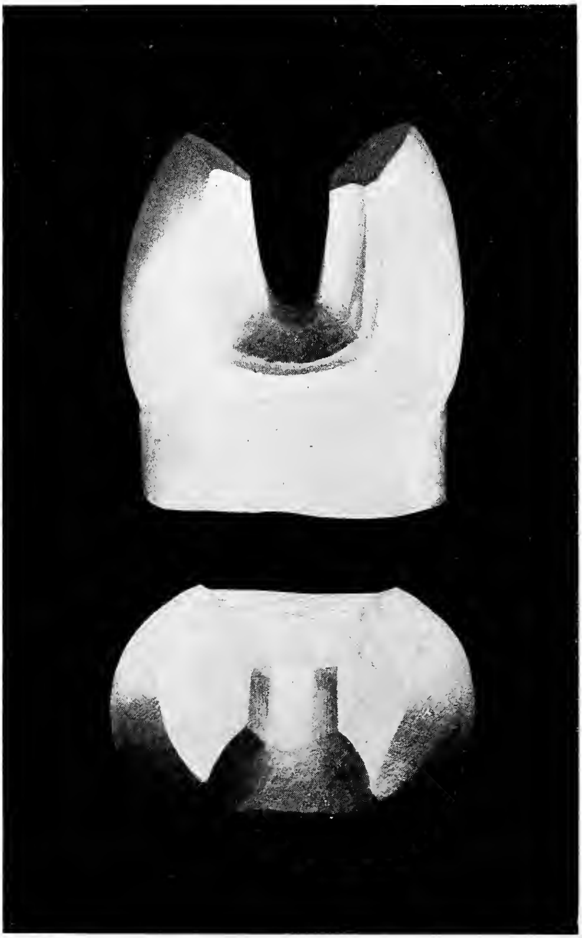

Plate VI.

Upper Bicuspid with Large Mesial and Distal Cavities (Tooth Pulpless).

The cavities are prepared in the usual manner, and the margin of the enamel bevelled. To prevent a subsequent fracture of the lingual or buccal wall, the inlay should completely cover the occlusal surface. The gold should have the greatest possible thickness and at the same time be invisible in the mouth. To accomplish this, the occlusal surface is bevelled lingually and bucally from the tips of the cusps toward the fissure with a diamond-disk.

Plate VII.

Upper Bicuspid with Lingual Wall Missing.

As the form of this tooth offers no broad seat for the inlay (as in plate III), a pin must usually be inserted. This should be placed as far lingually as possible. Its length is dependent upon the strength of the wall still standing. Proximally the enamel margin is bevelled slightly, while cervically it is broadly bevelled, especially at the lingual margin. The occlusal surface of the buccal wall is bevelled lingually. To make the gold invisible in the mouth, the hook retention should be cut into the distal margin, behind the cusp. If the wall is weak, a second hook retention mesially is necessary. In the preparation, special care should be exercised to make the wall (*a*, Fig. 25) on the buccal surface vertical, and sufficiently large.

Plate VII.

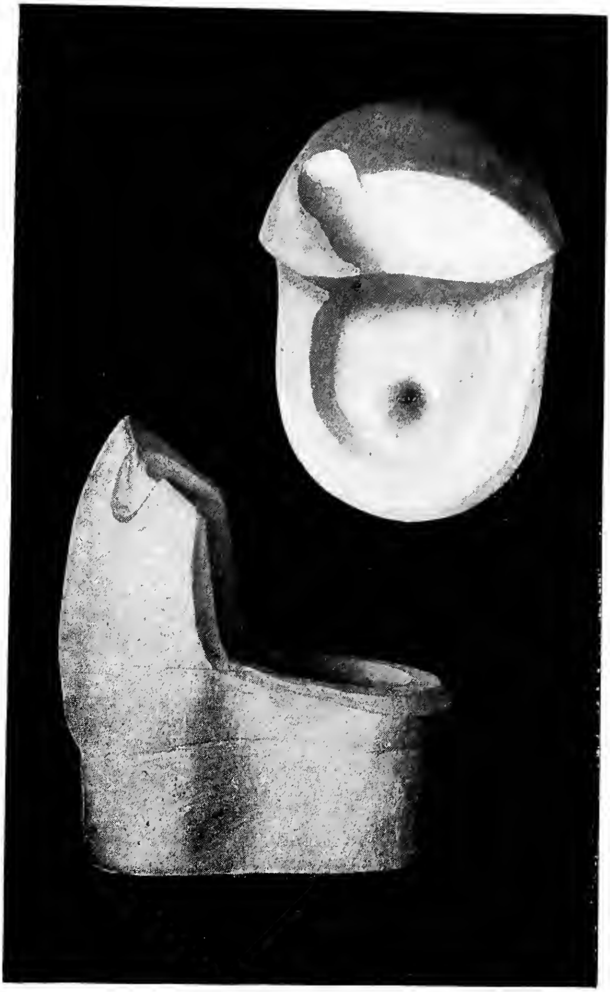

Plate VIII.

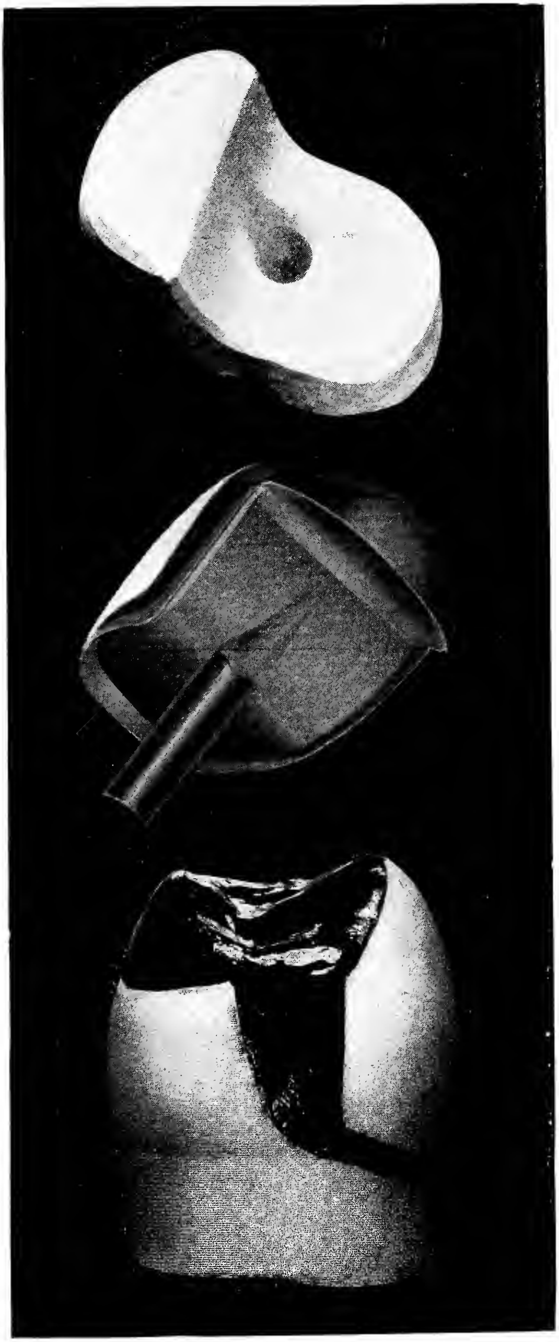

Plate VIII.

Upper Bicuspid with Buccal Wall Missing.

The remaining buccal portion of the tooth is ground off to the margin of the gum, and if possible, the edge bevelled buccally. The lingual cusp is removed and the surface sloped lingually. The margins of this surface are all broadly bevelled. The post, which should be long and strong, is placed into the canal, and an impression taken with a thin copper ring and modelling compound. The model is poured in Spence-metal. Upon this model, the porcelain facing selected is ground up. To permit the removal of the facing during casting, the pins are covered with moldine, and the facing well oiled. Upon the Spence model, the wax form, with post and facing in position but without an occlusal surface, is carved. This is then tried in the month, and after the position of the facing has been corrected and the margins smoothed, the wax is chilled. To prevent distortion at this stage, there should not be sufficient wax on the occlusal surface to come in contact with the antagonist. The form, having been thoroughly chilled, is removed from the mouth, dried, soft wax added upon the occlusal surface, and again placed in the tooth, and the patient requested to close quickly. By alternately chilling the form with cold water and softening the surface with hot air, a perfect articulation can be carved without disturbing the lower parts of the wax form previously completed. To prevent distortion of the wax, the post is firmly held in a pin-vise and the facing removed by the aid of a rod of sticky wax. The form is then cast, and the facing attached with cement. If but little of the lingual wall remains and the bite is favorable, regular porcelain teeth with occlusal surfaces can be used.

Plate IX.

Upper Bicuspid with Erosion.

If the margins of the defect are sharply marked, two semicircular steps are cut at right-angles to the surface of the tooth with a large fissur bur. The curved surfaces of these steps should lie opposite one another and be parallel to the direction in which the inlay can be removed from the cavity. At these points regular undercuts (Fig. 10) should be made in the tooth and in the inlay. If the margins of the defect are not sharply marked, they can easily be made so with a diamond disk.

Upper Biscuspid with Simple Cervical Cavity.

The upper and lower wall are to be made parallel and the margins bevelled (Fig. 39).

Plate IX.

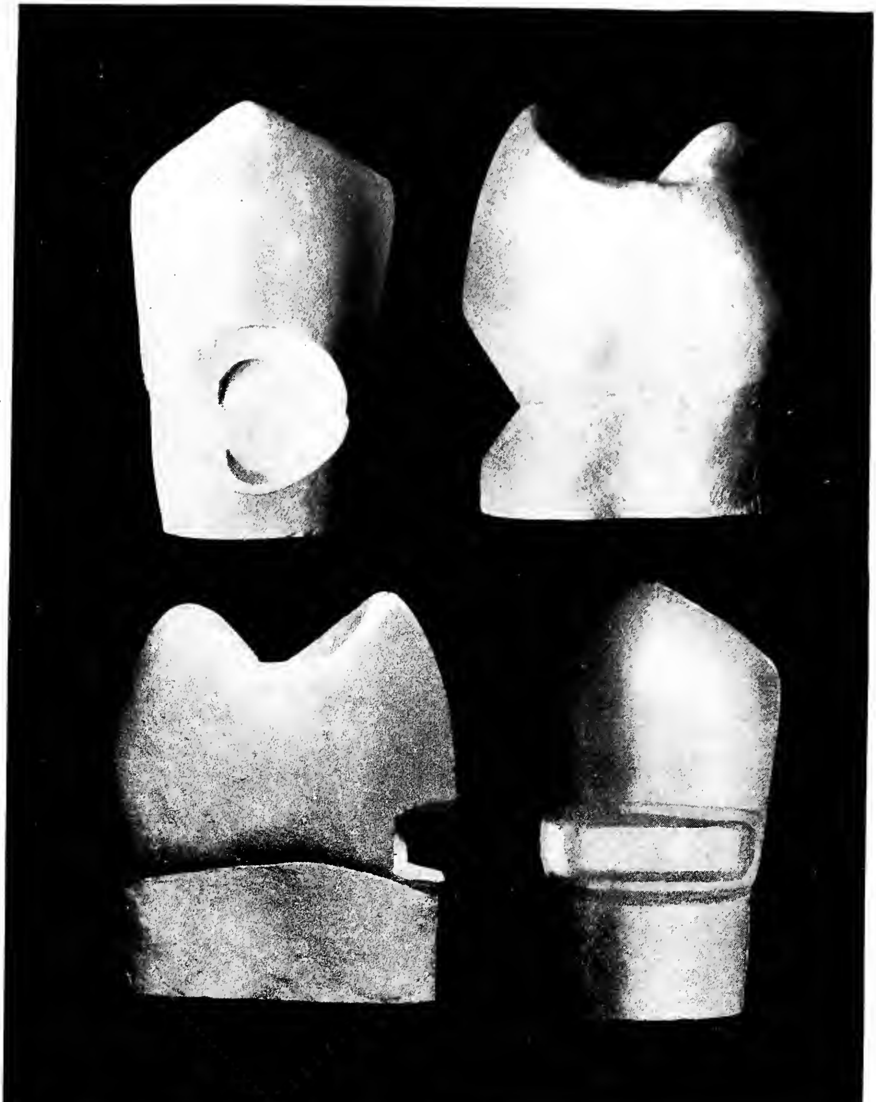

Plate X.

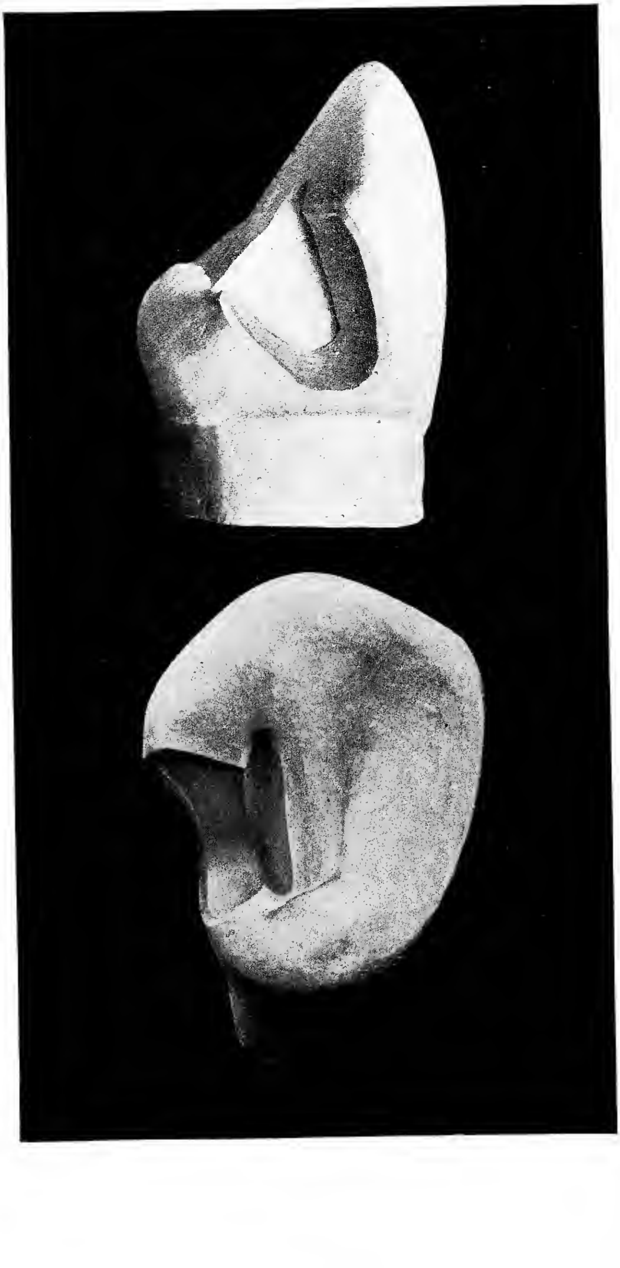

Plate X.

Cuspid with Small Distal Cavity.

The cavity should be prepared almost at right-angles to the lingual surface of the tooth. The margin is to be carefully bevelled. The labial groove is prepared vertically, the lingual, as horizontally as possible.

Plate XI.

Cuspid with Large Distal Cavity.

The distal angle of the tooth is removed with a disk. The labial surface is so cut out, that the walls of this part of the cavity lie parallel to the long axis of the tooth. (In the illustration this part has been cut out more broadly than necessary.) The labial groove should lie vertically and the lingual groove horizontally. The margin of the enamel should be bevelled only between the two grooves and in the region of the lingual cusp.

Plate XI.

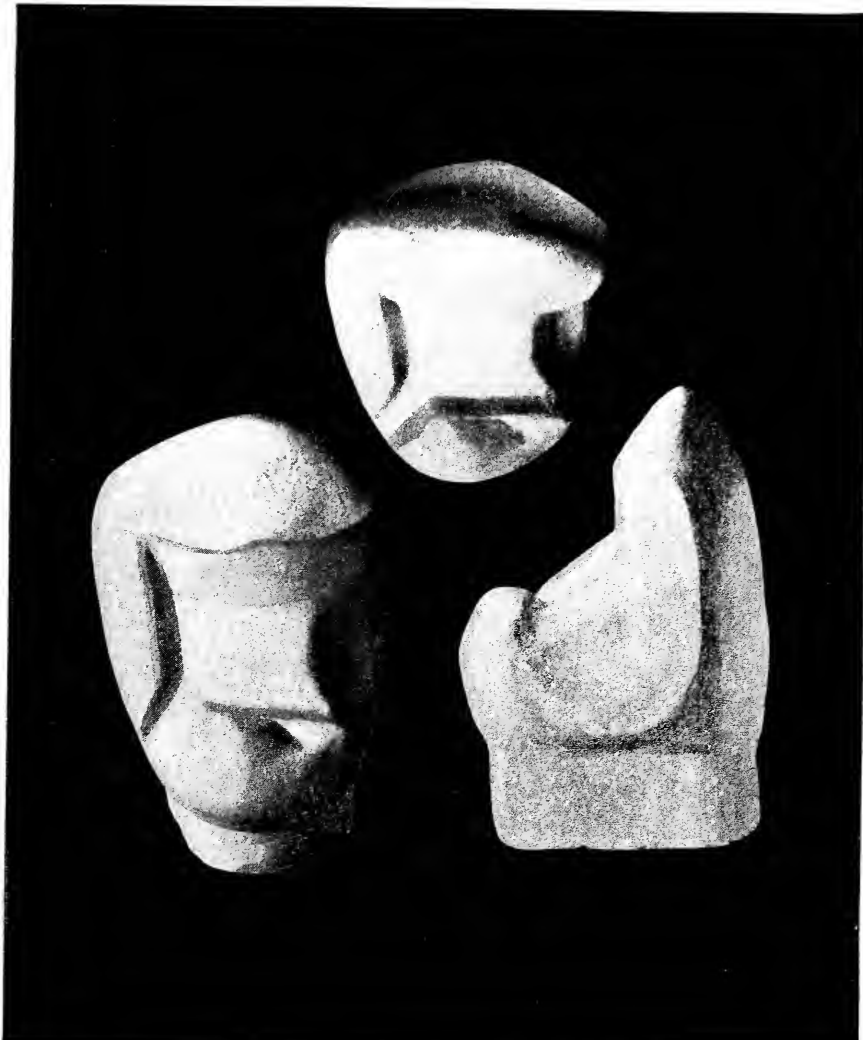

Plate XII.

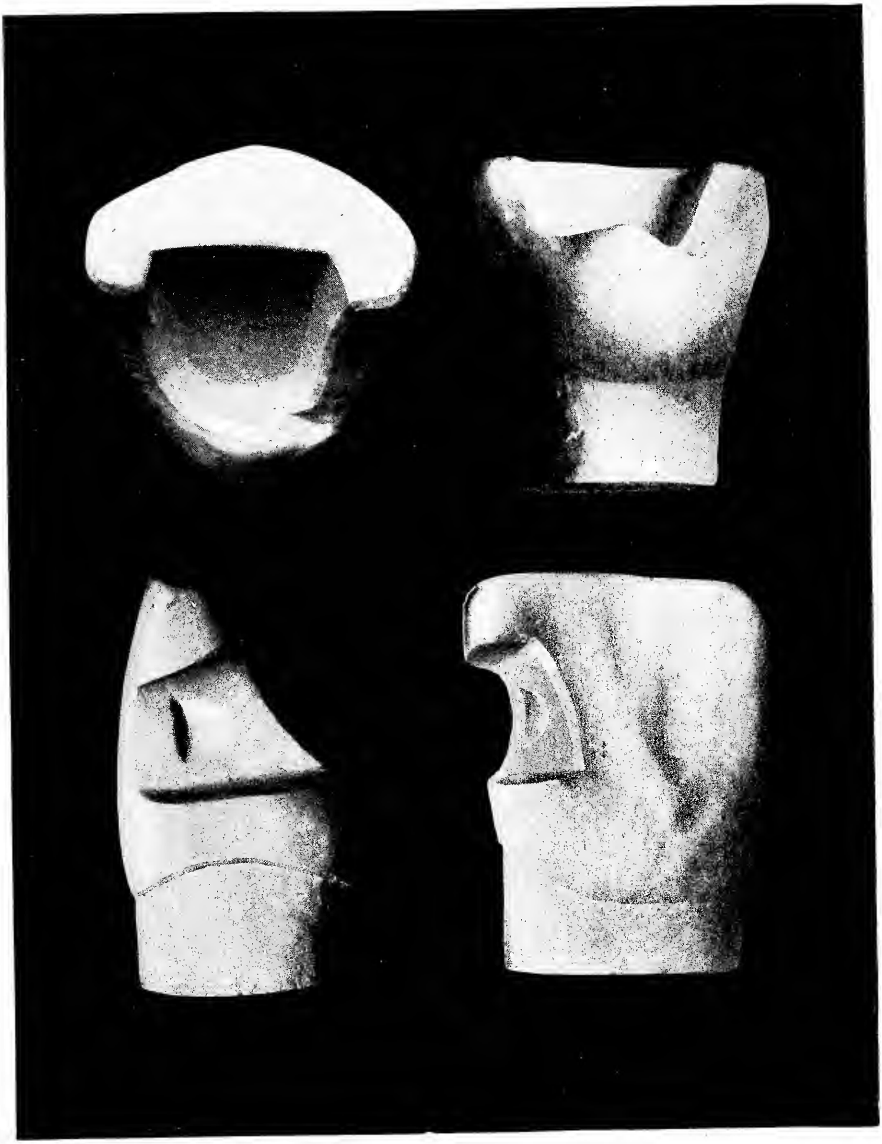

Plate XII.

Abraded Cuspid, with Inlay Anchored on the Lingual Surface.

This form of retention is used chiefly in cuspids and incisors with marked lingual abrasion. The incisive edge is ground off horizontally and the enamel margin bevelled. In the lingual surface of the tooth, a shallow cavity is cut, extending almost to the margin of the gum. Care should be taken to make the lingual wall vertical and as large as possible, as the retention of the inlay depends chiefly upon this wall of the cavity. On the lingual margin the enamel should be carefully bevelled.

Incisor with Small Proximal Cavity.

A metal inlay would not be indicated in a cavity of this kind. If, however, such a case should occur, the cavity could be prepared in a form recommended for porcelain inlays.

Plate XIII.

Incisor with Mesial and Distal Cavities.

In cases of this kind also, a metal inlay would hardly ever be indicated. At most, a combination inlay could be recommended, as the smaller cavity offers sufficient hold to allow the larger one to be filled partially with porcelain. (Figs. 102—104). The enamel margins should be but slightly bevelled, so as not to interfere with the removal of the impression.

Plate XIII.

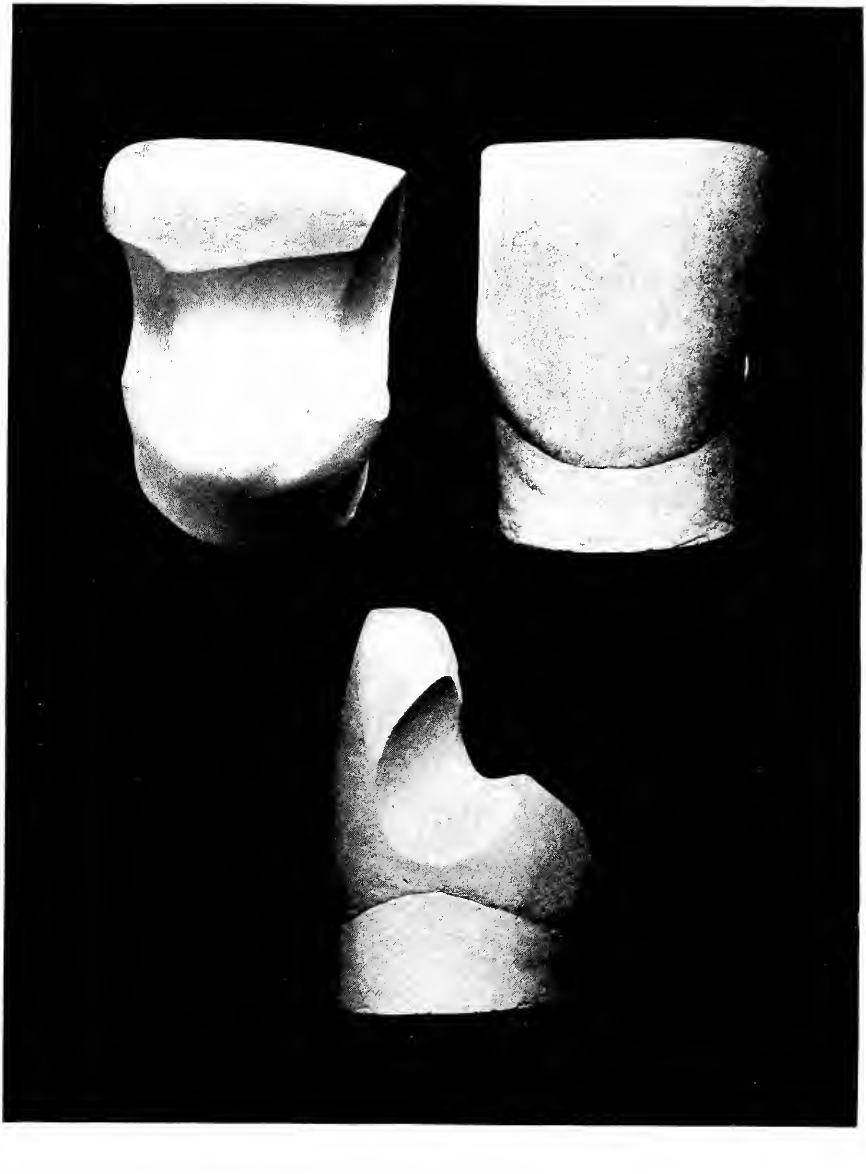

Plate XIV.

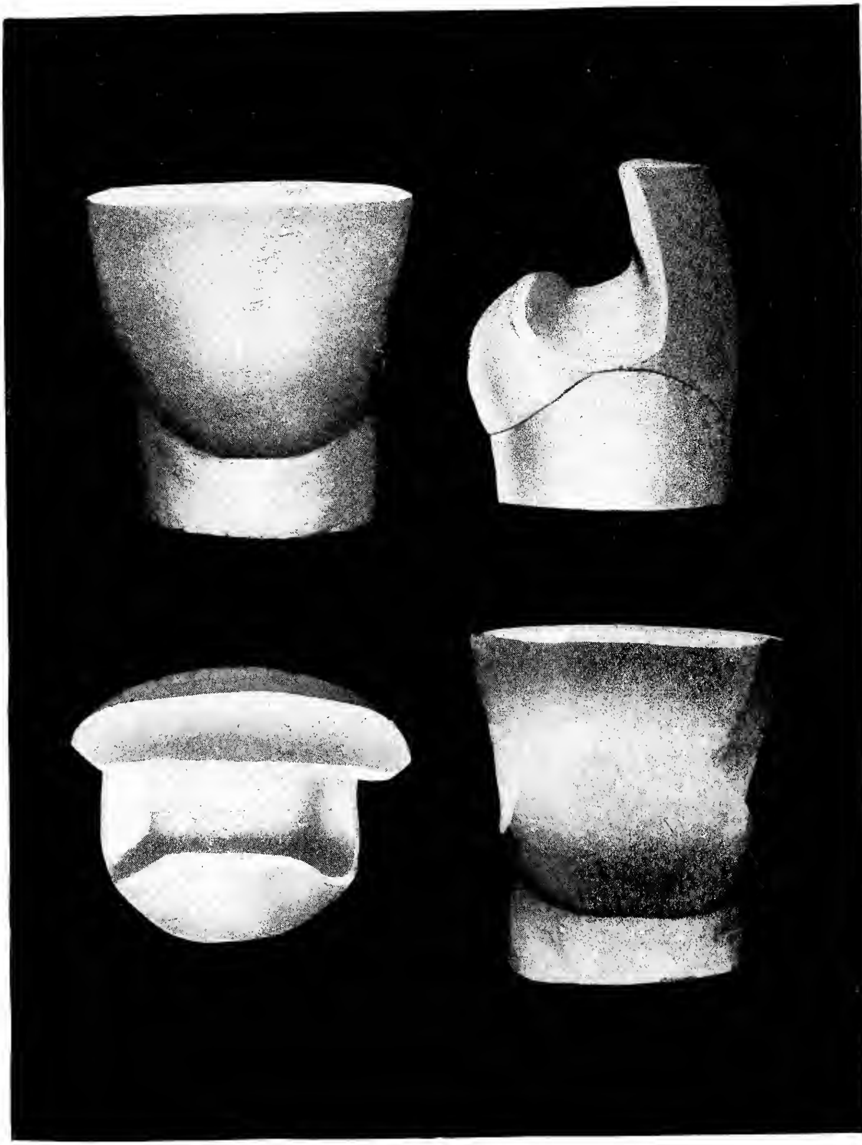

Plate XIV.

Abraded Incisor with Mesial and Distal Cavities.

Such cases are suitable for gold inlays, especially if the bite is strong. The incisive edge is bevelled labially and the proximal cavities so prepared that the impression can be removed easily. The final form of such a double cavities is dependent upon the extent of the caries upon the proximal surfaces, and will therefore vary with each case. The margins of the enamel should be carefully bevelled.

If the tooth is considerably abraded horizontally, and there is no caries on the proximal surfaces, the cavity for the inlay may be prepared in the box-shaped manner recommended for cohesive gold fillings*), with or without the pin-anchorage, as the case may require.

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*) L. Warnekros, Das Füllen der Zähne bei intakter Pulpa (Ash & Sons 1888).

Chapter IX.

The Impression.

The wax-model of an inlay may be made in two ways, either an impression of the cavity is taken in modeling compound and a cement model made upon which the wax form is built up, or the wax model is made directly in the cavity of the tooth. Strictly speaking, the wax-model, in each case, represents an impression of the cavity. The form made in the mouth may be called a direct impression, while that made on a model may be referred to as an indirect impression.

The indirect impression.

Since the first gold inlays were made, this method of taking impressions has been in use. Though the models at first were not very perfect, improvements in the methods, as well as of the impression compounds, have led to satisfactory results.

The impression compound should be made up in the form of cones and rods of different sizes. The impression of a simple cavity is taken with a rod-shaped piece of compound whose diameter is slightly greater than that of the cavity. The piece should be only about an inch in length, as otherwise it tips easily under pressure and gives a double impression of the margin. Only the tip of the rod is softened over an alcohol-flame, and the compound then pressed into the cavity at right-angles to the surface of the tooth. If the cavity is situated at the neck of the tooth, the harder material presses away the gum, thereby giving a perfect impression of the margins.

Cavities not possessing four walls, require some appliance to prevent the escape of impression material. Of these the most commonly used are thin copper rings. A supply of such

rings of all required sizes, should alway be kept on hand. In all larger cavities, unless the direction in which the impression may be removed from the cavity prevents, the copper ring is of the greatest service. If the form of the tooth or the position of the cavity makes the use of the ring impracticable, other means must be employed to prevent the escape of the impression material. Without describing the numerous appliances, it may be stated that they are all more or less modified matrices, similar to those used in making gold or amalgam fillings. Impression-trays or other appliances with long handles cannot be recommended. The almost inevitable lateral movement while pressing the material into the cavity and while holding it in this position until it has set, makes a double, or a distorted impression almost unavoidable.

The model may be made of one of the following materials: hard plaster, cement, amalgam, Spence or Melotte's metal.

The plaster model is the easiest to make, but has the disadvantage that if ordinary plaster is used, thin walls are liable to break off. With but little care in carving the wax form, a model made of the so-called alabaster plaster will do good service. This material is considerably harder than ordinary plaster, and sets, if salt has been added, in about half an hour. The hardest of all varieties of plaster, the so-called marble-plaster, has the disadvantage that it sets completely only in about twelve to sixteen hours. It then furnishes a model, equally as good as one made of cement or amalgam.

If the model is to be made of cement or of amalgam, the impression should be so imbedded in plaster, that it cannot be fractured by the force exerted in introducing the material. The cement need not possess great edge-strength, as it is not subjected to the high pressure formerly used in swedging the matrices for gold inlays. The cement for the model is mixed so that it is just kneadable, without sticking to the fingers. The mass is firmly pressed into the oiled impression, and the surplus formed under pressure, between the thumbs and index fingers, into a small pyramid. After the cement has set, in fifteen to sixty minutes according to the preparation used, the impression is removed and the model cleaned with chloroform.

Copper amalgam is the variety most commonly employed for models, as it may, by simply heating, be repealedly used. The preparation of the impression and the introduction of the material are the same as have been described for cement. The slowness in setting is the chief disadvantage of the amalgam model.

In making the model of Spence or Melotte's metal, the impression is embedded in Moldine surrounded with a ring, and cast under the usual precautions. By this method, in but a few minutes the finished model may be produced. With a good Spence metal, for example the White Inlay Metal, to which flowers of sulphur are occasionally added, the model presents smooth surfaces and sharp margins.

Upon the previously oiled model of the cavity, the wax form is carved. It is always advisable to try the wax form in the mouth before casting, in order to control the correctness of the bite, the contact point, and the margins. If the form cannot be tried in the mouth, the following method must be employed. After the impression of the cavity has been taken, a piece of fairly hard modelling compound, about the size of a hayel-nut is placed upon the cavity and the patient requested to occlude. The result is an impression of the margins of the cavity, the proximal surfaces of the adjoining teeth, and the occlusal surface of the antagonist. The model of the cavity is then placed in this impression so, that the margins of the cavity on the model and those in the impression exactly correspond. After attaching the cavity model to the impression with wax, the model of the bite is poured in plaster, in two parts. If the bite has been taken carefully, and the model of the cavity placed exactly in the bite impression, a true reproduction of the conditions in the mouth will be obtained. In spite of the greatest care, this method does not give as good results, as trying the wax form, previously carved on a model, in the mouth.

The direct impression.

Until lately, this method of taking an impression has not received the recognition of which it is worthy. It represents

in the field of metallic inlay technic, an advance, equal almost to the introduction of casting. It was necessary in the old swedged and soldered inlays to construct the form in three stages. First the impression in the mouth, then the cement model, and lastly the swedged matrix. Each of these stages represents a source of error for the perfect fit of the inlay. The introduction of casting, obviated the necessity of making a matrix, and it soon became evident by the better adaptation of the inlays, that one source of error at least, had been partially removed. Only partially, however, as the form must still, as in the indirect impression, pass through three stages. But the error with easily adaptable wax is far less than that with the stiff platinum matrix. Experience in the arts has shown, that in a series of models, each reproduced from the previous one, the form of the original becomes more altered with each subsequent model. Applied to the inlay process, it becomes evident that if the intermediary stages could be avoided, that is, the wax form made directly, without compound impression or model, a decided advantage for the inlay would be gained. In theory the method of making direct impressions rest upon a logical basis. In practice, the difficulties at first met with are due to inexperience and to the use of unsuitable instruments. Carving a wax form in the mouth requires the same care as making a cement or gutta-percha filling. As most operators have had no experience in the use of wax as a filling-material, its manipulation must first be learned. With patience and practice this is readily accomplished.

Before describing the process of taking a direct impression, a few words upon the qualities of the wax used for this purpose are necessary. Pure bees-wax cannot be used, as it is too soft and tough to carve well. Other substances must therefore be added to make it harder and more workable, as well as, to give it the other necessary qualities.

In making the form in the mouth, the hardness of the wax is of great importance. This being dependent upon temperature and the quantity of resins etc. added, a wax can be produced, that at 100 ° F will change its form only under considerable

pressure. For the hardening point of the wax, 100 ° F is about the most favorable temperature, as this is several degrees above that of the teeth when the mouth has been opened for a short time. If the hardening-point is below this, the wax remains soft in the mouth, and the form is very liable to be distorted during removal from the cavity. For the same reason, the form cannot be easily handled outside of the mouth, nor can it be carved while being held between the fingers. If the hardening-point is much above 100° F, the wax becomes brittle, and weaker processes and extensions are liable to break off even before the wax form can be removed from the cavity.

Intimately connected with the hardening of the wax, is its power of recovery. If two varieties of wax, both hardening at 80 ° F, are slowly heated until they begin to soften, and are then placed in water of 80 ° F, a marked difference in the time required for each variety to harden, and to regain its other qualities will be found. The inlay technic requires a wax with rapid recovery.

More or less related to the hardness of the wax, is the ease with which it can be scraped. A soft wax cannot be scraped, it can only be cut. This in an inlay-wax is not permissible, as in cutting the tough mass, the form would undoubtedly become distorted. Yet not every hard wax is suitable, as many of these also are tough. To test the scraping quality, the wax should be scraped at room temperature with a sharp instrument. The surface should be clear and smooth, and the scrapings be of a fine grain. Rubbed on the palm of the hand, they should not ball, but remain as small particles. The wax should not rapidly clog the grit of a sand-paper strip.

Another quality possessed by a good inlay wax, is cohesion at comparatively low temperature. This permits the wax being formed by hand, in each case so, that the bottom or the cervical margin of the cavity may with certainty be reached. Folds produced by the introduction of the wax into the cavity will disappear under pressure, thus making the model a perfectly homogeneous mass. Another advantage that a wax with marked cohesion at low temperature offers,

is that fresh wax may be added outside of the mouth, without danger of distorting the form through heat.

Under no circumstances should the wax be adhesive. Adhering to the instrument, it would make scraping impossible. It would also prevent the easy removal of the model from the cavity.

The wax should be sufficiently dark in color to readily show where it extends beyond the margin of the cavity. It should however not be so dark, that it is impossible to recognize the cavity margin through a thin layer. The coloring matter must contain no metal, as this would be deposited on the walls of the casting form when the wax is burned out, and thereby affect the surface of the inlay.

Convinced of the great value of the direct impression method, the writer performed a number of experiments, to determine the possibility of producing a wax having all the qualities described above. In how far he has suceeded, he leaves the profession to decide for itself.

Equal in importance to a good wax, are proper instruments. Even the most skilful operator is not able to produce a perfect wax model in the mouth without suitable instruments. It is not the intention of the writer to describe a complete set of instruments, sufficient for every case. Only a few, found to be of service will be mentioned. In all these instruments, the cutting edges should be as sharp as possible, so that the wax may be scraped without the exertion of pressure.

As a spatula the instrument shown in No. 1 (Fig. 93) may be used. To remove the excess upon the occlusal surface a spoon-shaped excavator, about a quarter of an inch in diameter is of service (No. 2). A smaller spoon (No. 3) is necessary to deepen the impressions made by the cusps of the antagonist. In carving the fissures, the instrument shown in No. 4 is used. This is a Darby-Perry excavator No. 3, the tip of which has been ground to a point. The angle made by the two cutting edges represents about the form of a fissure of a natural tooth. In modelling the proximal surface, the last three instruments are of service. For the coarser work,

a curved cement spatula (No. 5), and the spatulate end of a Woodson's amalgam instrument (No. 7). To model the less accessible cervical margin, the writer uses, the instrument No. 6. This is made by grinding a right-angled exploring instrument so, that in cross section it appears as a triangle. One side of the triangle should face the handle of the instrument. In scraping, the point is pressed against the neck

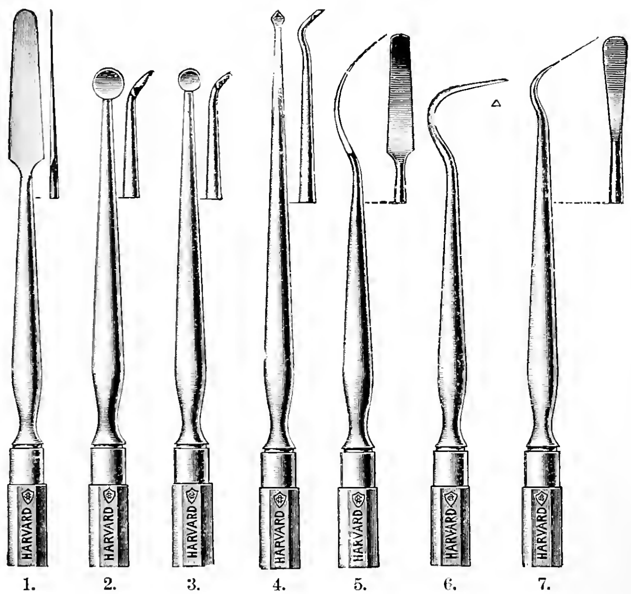

Fig. 93.

of the tooth, and all material overlapping the cervical margin thereby smoothly removed. In the same manner this instrument may be used to trim the other margins on the proximal surface. Beside the instruments mentioned, sand-paper or cloth strips are employed in modelling the wax in the mouth.

Every operator, in time, develops his own method of taking a direct impression. The following description is, therefore, intended only as a suggestion. Oiling the cavity is to be avoided, as a good inlay-wax is not adhesive. Before introducing the wax, the cavity is rinsed out with water. In exceptional cases cotton rolls are used to keep the field of opera-

tion dry. As this makes carving easier, it may be recommended to those trying this method for the first time.

The stick of wax is warmed *slowly* over an alcohol flame until it is so soft that a piece can be pinched off with the fingers, and kneaded. In warming, the surface of the wax should not be *overheated*, as this affects its power of recovery and its scraping qualities. The same is true of a prolonged kneading of the wax.

As an example, the disto-occlusal cavity of a lower molar has been chosen. If the interproximal space is large or unfavorable in form, as in the lower bicuspids, a matrix lightly held in position with cotton, is of advantage. The softened wax is formed into a cone, sufficiently slender to reach the bottom of the cavity. The surface of the cone is again softened in the flame and quickly introduced. With the index-finger firm downward pressure is brought to bear on the wax, until the proximal cavity is filled, then by drawing the finger forward under pressure, the excess wax is forced into the cavity on the occlusal surface. The patient is requested to occlude, and to keep the teeth together tightly at least thirty seconds, to allow the wax sufficient time to escape. In case the bite is very sharp, a small piece of thick rubber-dam should be laid over the wax before closure of the teeth. The danger of making the inlay too high, is thereby partially avoided.

The excess wax, lingually and buccally, is left untouched. Into the distal surface of the form, the right-angled exploring instrument is stuck as deeply as possible, and an attempt made to remove the whole mass from the cavity. If this is not successful, either undercuts are present, which must be filled out before a further attempt is made, or the wax is lodged against the neck of the adjoining tooth. In the latter case the wax in the interproximal space must be trimmed with the curved cement spatula (No. 5). The mass removed from the cavity is chilled in cold water, and may then be safely picked up in the fingers. The cavity surface of the form is examined and any evidence of undercuts or projections which might obstruct the removal of the impression, are scraped off with a small sharp spoon (No. 3). If on the lower part of the proxi-

mal surface a large surplus of wax is present, this may be removed partially before replacing the form in the cavity. The upper part of this surface, where the wax lies against the contact point of the adjoining tooth, should not be disturbed.

The wax is then replaced in the cavity. If much force was necessary in removing the mass in the first instance, the wax should be softened with warm water, and pressed snugly into the cavity with the finger. On the cervical part of the proximal surface pressure is exerted with the spatulate end of a Woodson's amalgam instrument (No. 7). If the bite is very sharp this should be done while the teeth are in occlusion. The patient having occluded, the wax, if necessary, is chilled and the occlusal surface carved.

A great excess of wax on this surface may, to save time, be partially removed with a warm, sharp spatula (No. 1). Usually it is best, however, to do all the scraping until the margins of the cavity appear, with the large spoon (No. 2). Depressions made by the cusps of the antagonist are then deepened with the small spoon. If the bite is sharp, the articulation may be controlled, by softening the surface of the wax with hot air. This must be done with great care, as only the very surface should be affected by the heat, to avoid subsequent contraction. Never should a small body of wax, or even the neighborhood of the margins of a larger body, be so treated. Upon cooling, this leaves a mat surface on which the impressions of the cusps of the antagonist can easily be seen. Such spots should again be deepened. Grooves, representing the fissures, are then scraped with the instrument No. 4. Only after the occlusal surface is completely finished, should work on the proximal surface be begun.

In order that the wax form may remain firmly fixed as long as possible, the margins of the proximal cavity are finished before modelling the proximal surface. For this purpose, the author prefers the three-cornered probe (No. 6). When the edges are smooth, the probe is again stuck firmly into the wax, preferably in the hole previously made, and the model lifted out of the cavity. An examination of the

form, shows whether the margins have been properly prepared, and whether there is still any wax overlapping the margins. In this case the form is replaced in the cavity, and the excess removed. If the point of the probe should slip over the margin of the cavity, and remove to much wax, more material must be added at this point.

The form is placed in a dish of cold water and all adherent blood and saliva washed off with a forcible stream of a water-syringe. The form, held between the fingers, is dried with the cold blast of a chip blower. Wax, softened upon the spatula until it just liquifies, is dripped upon the form as near the edge as possible at the place to be restored. The form is then quickly replaced in the cavity, and the soft wax pressed over the margin with the spatulate instrument No. 7. This must be done before the surface of the wax becomes moist, as otherwise the wax would not unite where it is accidentally folded in pressing the excess over the margin.

Modelling the contour, may be proceeded with when the margins are entirely satisfactory. For this purpose cloth-strips are of service. By carefully scraping the model, outside of the mouth, just sufficient space to admit the strip between the form and the adjoining tooth is made. In the neighborhood of the cervical margin the strip should lie snugly about the semi-circumference of the tooth, and be gently drawn to and fro. The nearer the contact-point is approached, however, the less should the strip, at the same time, encircle the whole contour of the wax-form. In finishing the buccal part of the proximal surface, the strip should enter the lingual side of the space loosely, and be drawn through in close contact with the buccal surface of the tooth. In finishing the lingual part of this surface, the above proceeding is reserved. When the wax is everywhere smooth, and the margins are perfect, the form is definitely finished. Before laying this wax model aside, the point, where the contact-point is to be placed, should be marked. The best way to preserve the wax models is to place them in a small dish, or glass containing cold water.

If regular undercuts are to be made in the inlay, this may be accomplished most easily upon the wax model, with the

instrument used in scraping the fissures (No. 4). In places were the inlay is to be specially roughened, it is advisable to scrape off a thin layer of wax, in order to increase the space between inlay and tooth at this point. If during the scraping, the model has been handled much, it should be given a final trial in the cavity.

With slight modifications, the method of making wax models described above, may be applied to all cavities. In very large cavities it is sometimes of advantage to first model, and finish that part of the form lying near the margins of the cavity, and later to add sufficient wax to build up the rest of the form. Where but little of the crown remains and a sharp bite tends to drive the wax out of the cavity, copper rings will be of service.

Special attention may be called to the advantage offered by the direct impression, in making large contoured inlays under the clasps of artificial dentures already present in the mouth. In preparing cavities of this description, the pressure exerted upon the inlay by the clasp in removing the denture, must always be taken into consideration. The wax is introduced into the cavity, preferably with the clasp in position. If this is not possible, the wax should be approximately modelled in the cavity and the denture, with clasp well warmed and oiled, then pressed into place. If the first attempt is not successful the procedure should be repeated.

The wax model to be placed upon the sprue wire, is removed from the water and laid upon a piece of blotting paper. The sprue which should not be of too small a diameter, is then heated, and a small quantity of wax melted upon the point. Into the wax model, held with the proximal surface uppermost, the point of the sprue is gently introduced at the place marked as the contact point. In mounting the form, the sprue should never be forcibly pressed into the wax. As soon as the wax has set, the form is replaced in cold water. After casting, the added wax and the sprue-stump furnish sufficient material for the construction of an ideal contact point (Fig. 94).

Beside a good wax and proper instruments, care and prac-

tice are necessary in making a direct impression. The advantages offered, however, are so numerous, that the writer feels confident, that in time this method will gain full recognition. Summed up briefly the advantages are the following:

1. The adaptation of the wax model at the margins can, with absolute certainty, be controlled in the mouth.
2. By repeatedly trying the form in the cavity, and by scraping away all possible obsctacles, the wax model can finally be removed from the cavity without distortion.

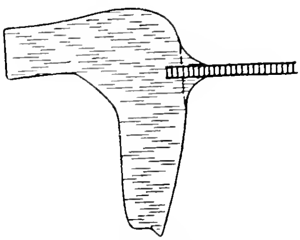

Fig. 94.

3. This results in a perfect adaptation of the inlay, making fitting unnecessary.
4. An ideal contact point can be made.
5. The occlusal surface is always adapted to the case.
6. Long and tedious grinding is thereby avoided while setting the inlay.

The only disadvantage which the direct impression possesses is, that if a failure in casting occurs, the time and labor expended upon the production of the wax model is lost. Under such circumstances, the indirect impression method offers the possibility of making a second wax form upon the model. If the failures in regard to adaptation of the inlay be examined, they will be found to depend upon three causes: 1. an inexact impression, 2. an imperfect model and 3. defective casting. If the failures due to each of these causes are numerically compared, it will be found that those due to defective casting are by far less numerous than those due to each of the other causes.

Hollow wax models.

To partially obviate the greatest disadvantages of the solid metallic inlays, that is, cost and conductivity, hollow casting has been resorted to. Castings of this kind are made, either by modelling the wax over a core, or by hollowing out the finished wax model. The first method, as practised by the writer, is as follows. Sodium bicarbonate is made up into pellets of different sizes, and these when dry, are coated with wax. For use, a pellet of suitable size is warmed, and lightly pressed into the cavity, care being taken not be approach the margins of the cavity too closely and to keep the surface dry. Soft inlay wax is then introduced into the cavity, and the form modelled in the usual manner. After mounting the wax model upon the sprue, a wide opening is made into the

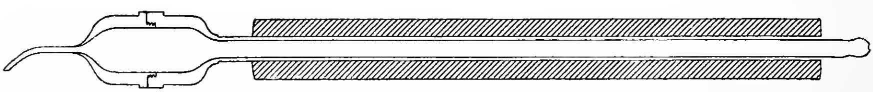

Fig. 95.

bicarbonate pellet with a hot, sharp instrument, and the form, then held by the sprue, is dipped into dilute sulphuric acid. The reaction is almost immediate. The opening into the chamber must be sufficiently large to prevent the button of investing material from breaking off during the process of casting.

The second method, which is perhaps more satisfactory than that described above, consist in drilling out a chamber, or in removing the necessary wax by aspiration. For this purpose F. E. Roach has constructed an instrument which does good service. Roach's Suction Wax Carver (section, Fig. 95) consists of a small, thick walled metal bulb, from one end of which a smaller bent tube protrudes. The other end is continued as a larger tube, covered with a non-conducting material, and serves as the handle of the apparatus. The end of this tube is connected with the saliva-pump, or taken into the mouth. For use, a pledget of cotton is placed

in the metal bulb, and the latter heated until smoke appears upon aspiration. The wax form mounted upon the sprue is then hollowed out. The wax being melted by the hot point is sucked into the tube and arrested by the cotton in the bulb. With this apparatus and a suitable wax, models with extremely thin walls can be produced.

Though the hollow inlay does reduce the conductivity as well as the cost of production, it does not give better retention, as has been so often stated. If in hollowing out the inlay the parallel walls are destroyed, the retention is endangered, and the work of having carefully prepared the cavity according to certain mechanical principles, will have been useless. The reason, that crowns of thin gold plate preserve a tooth, does not justify the assumption that inlays of the same thickness will be of equal service.

Chapter X.

The Construction of the Inlay.

The methods according to which metal inlays may be made, can be divided into two classes. In the first class the inlay is constructed upon a metal impression of the cavity, the matrix. In the second, gold is cast in a form exactly representing the part to be restored. The matrix-method has been entirely superseded by the casting process. The description of the methods of the first class will therefore be brief, and include only the chief types.

Of these the simplest and one of the oldest is the method suggested by Herbst (Bremen). The impression was taken with platinum-gold foil, in the manner later employed for porcelain inlays. The overhanging edges were coated with chalk, and the depression filled with low-fusing solder over an alcohol-flame. To facilitate handling and undercutting, a piece of gold wire was at the same time fused into the inlay. Held by the wire in a pair of pliers, the undercuts were made with a saw, and the surplus of the matrix trimmed off. The wire was then nipped off and the inlay set and polished.

According to a second method, whose originator is unknown to the writer, the inlay is made as follows. Gold or preferably platinum-gold foil is adapted to the cavity, and sponge-gold, under light pressure filled in, until the contours,etc are restored. If the sponge-gold does not adhere, the matrix may be coated with a sticky varnish. The matrix is carefully removed from the cavity, and the overhanging edges (and if the bottom is torn, the lower surface also) coated with chalk or rouge. It is then heated upon charcoal, and a strip of 18—20 kar. solder held upon the surface of the sponge-gold until it becomes saturated. Thereupon the inlay is trimmed and set in the cavity. A more agreeable color may be produced by using a platinum matrix and 22 kar. gold.

Sponge-gold inlays were also produced without the use of a matrix. According to this method, still used by some practitioners for certain cases, the sponge-gold is filled directly into the cavity, under slight pressure. At the margins there should be an excess and a slight overlap of the gold. This is well burnished against the margin of the cavity. The filling is removed with a probe, the cavity surface coated, and then saturated with 16—18 kar. solder. The inlay is set and finished in the usual manner.

In the methods just described, the matrix was made directly in the cavity; in the following methods a model is necessary for swedging the matrix.

The inlay most extensively used before the introduction of casting was, what might for the lack of a better name be called the soldered inlay, as it was chiefly composed of this material. The cement model of the cavity, made as described under the indirect impression method, is embedded in impression compound in the cup of a swedging press. Platinum foil is adapted to the model, and the cavity well filled with spunk. The cup is then placed in a strong cylinder with the rubber cushion and plunger in position, and put under strong pressure. The matrix is carefully removed from the model and the walls of the cavity reinforced with pure gold. It is then replaced on the model and again put under pressure. To prevent distortion of the matrix, the cavity is filled with sticky-wax before removal from the model. The wax is burned out, and the overhanging margins and the whole lower surface of the matrix is coated with chalk. The cavity is then filled out with solder, the use of borax being avoided as much as possible. Beginning with 22 kar., and only heating sufficiently each time to fuse the solder added last, the cavity is gradually filled with 22, 20, 18, and even if necessary with 16 kar. solder. The object should be from the start to place sufficient solder in the cavity to complete the inlay in one heating, without having to add a second or third time. Cusps and contour are produced by building up with sponge-gold and saturating with a low grade solder. The inlay is finished and set as above.

Larger parts of the tooth are restored, in the following manner: after the matrix has been reinforced and swedged for the second time, the missing contour is built up in hard wax. A piece of pure gold plate rolled extremely thin, is cut to shape, and burnished against the wax. The plate should lie in close contact with the margins of the matrix. If an occlusal surface is to be restored, a suitable cap is swedged upon die-plate and waxed upon the matrix. A part of one surface, proximal or occlusal, must always remain uncovered for the introduction of the solder. With the exception of this opening, the matrix with the wax and plate is embedded in asbestos powder. After drying, the wax is burned out and the chamber filled with solder.

The inlays described so far are all solid, a large number of methods, however, have been suggested for making hollow swedged inlays. The following method, devised in its essentials by Hinman (Atlanta), is as follows. For swedging, the small S. S. White press was used. The impression of the cavity, taken in the usual manner, is embedded in moldine, and well oiled. The cup of this press is inverted over the impression and through the hole in the bottom of the cup "inlay-metal", an improved Spence metal, is poured. The model being cleaned, is ready for immediate use.

The matrix should be made of rolled gold No. 60. Platinum gold of this thickness is, however, preferable. The foil is adapted to the model and covered with a rubber disk. The cylinder of the press is filled with moldine, placed over the cup and the plunger introduced. The latter is given a few light blows with a heavy hammer. The matrix is removed, reinforced, a hole cut into the bottom, and then reswedged. The model is then filled with wax, and the contour and occlusal surface carved. If possible this wax model is tried in the mouth. The wax is again placed upon the Spence model, the surfaces smoothed, and an amount carved away from the margins of the cavity equal to the thickness of the gold used for outer part of the inlay. An impression of the wax form is then taken and cast in "inlay metal". The cap swedged upon this second model, is carefully soldered from the outside with

20 kar. solder upon the matrix, while through to hole cut in the bottom, the inside is thoroughly reinforced with 14—16 kar. solder. In setting the inlay into the cavity, the chamber is filled with cement.

For making this class of inlays (Fig. 57), preeminent before the introduction of casting, a large number of methods have been devised. To-day such inlays are never made. Their disadvantage is not alone the difficulty of construction, but also the inadaptability of the margin, as a result of soldering the two parts together. The hardness of the gold makes burnishing the margins impossible. The only advantages which at that time could be claimed for this class of inlays were, that they saved valuable metal, and that being filled with cement, they were not as good conductors of temperature as solid metallic fillings.

The Casting Process.

The wax model, mounted as described on page 100, is washed off with alcohol. The sprue is placed upon the sprue-holder, and together with the model, coated with investment material of creamy consistency. The cup or casting-ring is then filled with the same material, the sprue-holder inverted, and allowed to gently settle down until its edges are in contact with the cup; or the ring may be placed in position and filled from above. The investment material must be so soft, that pressure is never necessary in embedding. As soon as the investment has set, the sprue-holder is removed, and the form gently heated until the sprue can be withdrawn. The heat is then gradually increased. In about half an hour the wax has been thoroughly burned out, and a smooth walled chamber remains. The form is then ready to be cast by any one of the different casting processes.

The investment material.

Before describing the different systems of casting inlays, a few words on the subject of investment materials, and on the casting of metals in general are deemed necessary. All

of the innumerable materials recommended for the investment of metallic inlays are by no means satisfactory in practice. Which of these is the best, or if any one of them possesses all the necessary qualities of a perfect investment material, are questions that can be determined only by a long series of experiments or comparative tests.

The qualities which an ideal material, used as an investment for the production of inlay casting-forms should possess, are briefly summed up below.

1. The material mixed to a thick creamy consistency, should set, without contracting, within a quarter of an hour.
2. In drying and heating the mold, the material should neither crack, burn, fuse, soften or change its form in any way.
3. After the wax has been burnt out, the walls of the form should be perfectly smooth.
4. The material should be sufficiently porous, to permit the escape of the air compressed in the form during casting.
5. A quality which the material should possess in a high degree, is non-conductivity of heat. The more marked this quality in an investment, the less need the metal to be cast, be heated above its fusing point.
6. The material must be hard enough, and possess sufficient edge-strength, to withstand the pressure of casting.
7. The material should not be disintegrated by the heat of the molten metal. An investment, unsatisfactory as regards the last two points (6 and 7), cannot be used to cast inlays of complex form. The angles, which on the cavity surface of the wax model were well defined, would in the inlay appear quite rounded. The inlay would then not fit into the cavity.
8. The investing material should contain no substance, which under the action of the heat of the molten metal, becomes adherent to the surface of the inlay.

To prevent the formation of bubbles, the material must be slowly and carefully mixed. Though some investments are more liable than others to the formation of bubbles, correct

mixing and embedding will usually obviate this difficulty. Tapping the cup or ring after the wax model has been embedded will inevitably lead to the formation of bubbles. The cup is tapped on the supposition that all bubbles will thereby rise to the surface. This is, however, not the case. Gas bubbles are strongly attracted by any foreign body present in a liquid or semi-liquid medium. The bubbles will therefore collect upon the surface of the wax-model, and no amount of tapping can then dislodge them.

A number of methods have been suggested for the prevention of bubbles in the investment. The simplest is probably the use of recently boiled water. The writer found this to be used in the arts, in making fine plaster casts*). Contrary to expectations, this procedure has given very satisfactory results. Another method, suggested by the writer, is to place the water or even the ready mixed investment material under the bell-jar of an exhaust pump. After exhauting the air, the wax-model is carefully embedded in the usual manner. The necessity of an expensive apparatus, is the objection to this method. Price**), on the other hand, compresses the air contained in the investment material. The top of the cup, with the recently embedded model is covered with a layer of wax and placed, until the investment has set, in a hydraulic press capable of exerting a pressure of 70—80 atmospheres. The plastic material is thereby forced into the finest details of the wax form, and the bubbles, in obedience to the law of the volume of gases under pressure, are decreased to $^1/_{70}$ or $^1/_{80}$ of their normal volume. Price says: "This produces a model of great density and smoothness of surfaces, and when applied to an investment around a wax-model has a most beautiful effect on the surface of the cast gold, and the greatly increased density produces a harder investment, and one with greater expansion." The latter is, according to Price, a very valuable quality. He argues, that as cast gold even under the most favorable circumstances shows a contraction

*) Ed. Uhlenhuth, Formen und Gießen (Leipzig).

**) Weston A. Price, The Laws Determining Casting or Fusing Results, etc. Items of Interest No. 3, 5 u. 6, 1908.

of 1.3 per cent, an investment material with an expansion of exactly the same amount, would correct this error. Such an ideal investment material, having all the other necessary qualities, has as yet, not been produced.

The amount of material used for investing, and consequently the size of the cup, should be in proportion to the size of the wax-model. As all investments expand more or less upon being heated, the walls of the mould should be of the same thickness at all points. This insures a uniform expansion, preserving the correct proportion in the inlay. If a wall is thin, yet sufficiently strong to withstand the pressure of casting, it will expand less, and consequently the inlay will be flattened on that side. If the wall cannot withstand the pressure, it will either be bulged out or cracked in casting. "The best that any of the investments now available will do is to expand 8,5 thousanths*) as a maximum at 1000 degrees F." (Price), and as the metal of a steel or brass cup has a coefficient of expansion of about twice this amount, it becomes evident, that the mould receives but little support from the cup or ring when it is heated. This proves the necessity of making the walls of the mold sufficiently thick.

Price calls attention to the fact that the investment must be homogeneous. His experiments have proven, that different investment materials do not expand equally, and that this is true of even a thin and a thick mix of the same material. If therefore the wax model is coated with a thin mix, and the cup filled with a thicker mix of the same material or even with another investment, failure becomes imminent, owing to unequal expansion of the mould. Cracks and crevisses are formed, or the inner layer of investment may in places break away from the outer.

The mould should be dried slowly and uniformly. If the investment contains much plaster, drying may be more rapid. The water and wax boil out of the sprue gate without doing the mould any harm. The disadvantage of such material is that it checks easily in heating, and that it is disintegrated

*) Taggart's Investing Material.

by the heat of the metal. After the mould is dry, it must be further heated to burn out every trace of wax. Tests made by the writer have shown that this takes place at a temperature of about 450 ° C. (842 degrees F.) The wax passes off as a blue vapor, and a deposit of carbon blackens the sprue-gate. Continued heating causes the deposit to disappear gradually until the gate has resumed its natural color, only a dark ring remaining upon the surface of the mould. Every trace of wax has then been burned out, and the temperature in the chamber of the mould is about 850—900 degrees F.

With some investments, it is not advisable to allow too long a time to intervene between embedding the model and burning out the wax. While standing the investment looses moisture, so that when the mould is heated, the wax instead of boiling out of the sprue-gate with the water, is absorbed by the investment. This, in some cases, seems to have a deleterious effect, producing an inlay with very rough surfaces. The same effect is produced by heating such investments too slowly.

An investment material, perfect in every respect, is up to date, unknown to the writer. Price's artifical stone, though not an investment in the strictest sense, possess many of the most desirable qualities. It is a body equally related to the portland and silicate cements. For mixing an orthophosphoric acid of definite specific gravity is used. This material is hard, dense, and very resistent to temperatures up to 2700 degrees F. Its linear coefficient of contraction in setting is "in some cases as low as two-thousandths per linear inch". The stone model is made from an impression, the cavity in the model waxed up, and the model with the wax in position embedded in investing material in the usual manner.

An investment recommended by W. Sachs (Berlin), and extensively used in the northern part of Germany, consists of

Quartz flour . . . . . 2 parts
Plaster . . . . 1 part (by volume).

The quartz flour, an almost perfectly pure silica, is obtained from the Royal Prussian Porcelain Factory. The ingredients should be well mixed, preferably in a rotary flour

sieve. Another investment, which has been recommended by Arvine*), consists of

English porcelain clay .	1	part
Quartz flour	1	part
Plaster	1,5	parts (by weight).

M. L. Ward (Ann Arbor)*) after carefully studying the subject of investing materials, believes that a material for this purpose, to be strong, must have a composition analogous to that of concrete. This is a mass composed of gravel in which the spaces are filled out by sand, and the spaces beween the grains of sand are in turn filled out by cement. In the investment suggested, the gravel is represented by flint powder, the sand by quartz flour, and the cement by plaster. The proportions as given,

Flint	30 cc.
Quartz flour	36 cc.
Plaster of Paris	17 cc.

refer only to the materials used by Dr. Ward. The grit of the silicates and the quality of the plaster are the factors which determine the relative quantities of the formula.

The casting-metal.

Only the noble metals and their alloys are used in casting inlays. They possess all the qualities, necessary for sucessful casting. These metals may be fused with the flame of an ordinary blow-pipe, and become sufficiently fluid to reproduce the finest details of the mold. In common with all metals, they possess the property of contracting after having been cast. The contraction occurs in three different stages; 1. contraction of the overheated metal in its liquid state, 2. contraction at the moment of solidification, and 3. contraction of the solid metal while cooling. An exception to this rule is made by cast-iron, bismuth, and some alloys of copper and tin. These expand more or less at the moment of solidification. In the third stage they again act like other metals.

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*) F. B. Arvine, Gold Cast Inlay Investment, Cosmos, No. 1, 1908.

**) Marcus L. Ward. A Consideration of the Casting Process, with Special Reference to Refractory Materials. Dental Cosmos, Sept. 1909.

Uhlenhuth gives the linear coefficient of contraction of some of the baser metals as:

	from	to	average
Zink	$^1/_{65}$	$^1/_{57}$	$^1/_{62}$
Lead	$^1/_{101}$	$^1/_{86}$	$^1/_{92}$
Tin	$^1/_{173}$	$^1/_{120}$	$^1/_{147}$
Statuary-bronze	—	—	$^1/_{120}$
Brass	$^1/_{79}$	$^1/_{49}$	$^1/_{65}$
Cast iron	$^1/_{98}$	$^1/_{95}$	$^1/_{96}$
Gun-metal (100 copper, $12^1/_2$ tin)	$^1/_{139}$	$^1/_{130}$	$^1/_{135}$
Bell metal (100 copper, 18 tin)	—	—	$^1/_{63}$
Steel	—	—	$^1/_{65}$

"The cubical coefficient of contraction, is found by trebling the above fractions while for the coefficient for a surface, the fractions are doubled. A cube of cast-iron will therefore shrink along each edge $^1/_{96}$, upon each surface $^1/_{48}$ and in cubical contents $^1/_{32}$."

In regard to the shrinkage of the noble metals as determined by W. A. Price, the appended table, though incomplete, shows some interesting points. The linear coefficient of contraction is given in thousandths. The influence of pressure upon shrinkage is also shown.

Pressure	Gold 24 kar.	Gold 18 kar.	Gold solder (Gold 18, Silver 2, Copper 2, Zink 2 parts)	Silver (pure)	Gold and 10 % Platinum
0	22.5($^1/_{45}$)*)	—	—	—	—
$^1/_{50}$ oz.	20.5	—	18	—	—
$^1/_{10}$ „	18	—	—	—	—
3 pounds	14	—	—	20 ($^1/_{50}$)	—
$5^1/_2$ „	13 ($^1/_{77}$)	15.5	15	—	14

*) Converted into fractions as in the table of Uhlenhuth.

That the gold used in casting an inlay does shrink, is an indisputable fact. The amount of shrinkage, as well as the

best method of controlling it, are subjects upon which opinions differ widely. Ward*) beleives the shrinkage in a properly cast inlay to be far below the percentage given by Price. As the coefficient of contraction of cast-iron decreases in direct proportion with the size of the casting, Dr. Lane argues by analogy, that as Price determined the percentage of shrinkage on gold bars, the percentage of a small inlay would be proportionately less. Upon this theory, the actual shrinkage of a pure gold inlay of $^1/_4$ inch in diameter is stated to be 0,0008 in. This leaves a space of 0,0004 in. on each side between the walls of the cavity and the inlay. This could be filled only with the finest grained cement. (See Head's table p. 140.) The progressive variation in the coefficient of contraction is accounted for by the more rapid chilling of the smaller masses of metal immediately after being cast. In order to cast inlays with such low shrinkage, the mold should be cool, and the gold as fluid as possible without being heated much above its fusing point. The casting machine must, therefore, be quick and reliable in action.

Lane**) found by a series of experiments, that the amount of pressure has no influence on shrinkage, as long as an exceedingly hot mold is used. Equally good results were obtained by using 45 or 5 pounds pressure per square inch. Castings made from a half-inch pattern, showed a shrinkage of 0,0008 inch.

Van Horn***) recommends the use of a superheated mold. He, however, does not believe that this measure alone will prevent shrinkage. This is accomplished by determining the coefficient of expansion of the wax used, and making the mold with a correspondingly hot investing material. (115 to 120° F.) The wax expanding uniformly, produces a slightly enlarged mold, which in turn neutralizes the contraction of the gold. By this method, it is possible to produce castings which are even larger than the patterns.

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*) M. L. Ward. A Consideration of the Casting Process etc. Dental Cosmos, Sept. 1909.

**) Dental Digest, July, 1909, p. 498.

***) C. S. van Horn. Casting: A Review and Commentary, etc. Dental Cosmos, August 1910.

Price*), in regard to shrinkage, says "that gold does contract a definite amount no matter when, how, or by whom it is manipulated, and that this total contraction will take place under all conditions, though its exact position may be changed in part; that is, as the mass of gold making up the inlay and sprue is cooling, the gold may be moved from the sprue to take up some of the total of the contracted gold in the inlay." In another article Price claims that "the location of the shrinkage or contraction (not the total amount) can be partially transferred to another part of the cooling mass by pressure on the molten gold while it is in a semi-molten state, and that the distance or range in temperature below the melting or fluid point through which it can be moved from one part of the mass to another to take the place of contraction at that latter place, is dependent upon the pressure used." Price therefore claims that high pressure is the only reliable means of preventing, or at least controlling, shrinkage. This, of course, necessitates the use of high pressure machines in connection with the stone model, as ordinary investments would under such circumstances be worth less.

From the opinions quoted, it becomes evident that this question is far from being settled. Granting the accuracy of the experimental data in each case, it remains for future investigations to prove the fallacy of some of the deductions.

Mention has been made of the fact, that the shrinkage of metals occurs in three stages.

1. Shrinkage of the molten metal.
2. Shrinkage during solidification.
3. Shrinkage of the solid metal upon cooling.

For gold, only the shrinkage during the third stage has been investigated. It may be safely assumed that any measure taken to influence the shrinkage in this stage will have but very little effect. Price found that the melting point, and therefore also the point of solidification, of gold, could, by high

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*) Weston A. Price. Some Advantages of the Stone Model Method etc. Dental Cosmos, Sept. 1910.

**) Items of Interest, Sept. 1910.

pressure, be reduced as much as 200° F. The question arises whether the pressure prolongs the process of crystallization, or whether the point is simply reduced 200°, while the process itself goes on in the time and manner as under normal conditions. Price believes that as gold shrinks 0,001 with every 100° F. under the fusing point, by lowering the fusing point 200°, the shrinkage is reduced by 0,002. A thorough investigation of the phenomena in the second stage of shrinkage (solidification) will probably explain why contrary methods of casting seem to give the same results. That metals in this stage obey some special laws, is proven by the fact that cast-iron, in contradistinction to most other metals, expands to such an extent during solidification, that it is liable to burst all but the strongest molds.

Any metal heated above its fusing point, will, with increasing temperature, constantly expand. After casting an inlay, the pressure equalizes the resultant contraction up to the moment of solidification, by forcing liquid metal into the mould to counteract the shrinkage. If, however, the channel is long and narrow, the material used for investment not a poor conductor, and the metal overheated, then the metal in the channel will solidify while the metal in the cavity of the mould is still liquid. When the latter gradually cools, no additional metal can then be forced into the mould to replace the shrinkage. The dead-head, or excess metal in the channel, usually parts from the casting at the point where it enters the chamber of the mould. This condition, known as blowing, is recognized on an inlay by the presence of more or less irregular depressions about the dead-head. The latter does not always tear away from the inlay and may be normal in appearance, in spite of the presence of blow-holes. Foreign matter in the casting metal may produce the same conditions, by obstructing the free flow in the channel. To prevent the formation of blow-holes, special attention should be paid to the quality of the investment used, as well as to the cleanness and the heating of the metal. The reason for using a short sprue, which in diameter is proportionate to the size of the inlay, is evident. Perfect fluidity of the metal is absolutely

essential to successful casting. Foreign matter, traces of investing material, products of oxidation, and other metals are contaminations which tend to reduce the fluidity of the metal, and should, therefore, be carefully removed before casting. Foreign matter need be considered only if the gold has been accidentally spilled. Investing material can be removed by dilute hydrofluoric acid. The products of oxidation and other metallic contaminations are removed only by refining the gold. For this purpose Ward*) recommends the dry process. "A number of different methods of purifying gold might be enumerated, but perhaps nothing will ever be of more service than about equal parts of potassium nitrate and borax. Both are clean white powders which can be mixed and kept in an accessible place. If a casting is about to be made, and the gold is found to be too sluggish, the operation need not be delayed much over five minutes to purify the gold, while ten or fifteen minutes would raise the karat considerably. The process involves the oxidation of the base metals, the oxygen being furnished by the potassium nitrate, and these oxids being separated from the gold beneath the flux of borax. The gold should be melted and the mixture added a little at a time with one hand, and a blowpipe flame kept directed on the gold with the other, the gold all the time being kept melted. This should be continued in most cases for about five minutes, though it is often necessary to continue the process much longer. As soon as the last particles of nitrate and borax have been put on the gold the flame should be removed, to avoid its contaminating influence. Gold known to contain certain quantities of tin, silver, or lead could perhaps best be refined by the ammonium or mercuric chlorid process, but for iron, bismuth, antimony, zinc, etc., nothing excels potassium nitrate and borax."

The metal almost exclusively used in casting inlays, is gold. Opinions differ, however, in regard to the fineness. Most operators prefer to use 22 kar. gold, while the writer, for reasons described in chapter II and XI, generally makes his inlays of 24 kar. In cases where the anchorage extension must

*) M. L. Ward, Dental Cosmos. Sept. 1909.

bear considerable strain, or where abraded occlusal surfaces are to be restored, 22 kar. gold is undoubtedly preferable.

A number of inlays of pure silver have been made by the writer. The only objection to this metal is that it often turns black in the mouth. It casts well, and can without difficulty be burnished against the margins of the cavity. Being as servicable as gold and requiring the same cavity preparation, yet costing much less, the silver inlay would be of use in college infirmary practice.

Though platinum can be cast in special apparatus, its high melting point makes its use in inlay work almost impossible. The writer has cast inlays of this metal, using the Jameson apparatus and a gas-oxygen flame, and melting the metal in a specialy constructed crucible. The results were only occasionally satisfactory. Platinum inlays would be useful, for combination with high-fusing porcelain (Figs. 102—105). Dental alloy, silver and platinum, does not always keep its color in the mouth.

Gold, owing to its color and its contraction, cannot be designated as an ideal material for making inlays. Such a metal would have to be constant in form, and possess the durability and malleability of gold, the cheapness of silver and soft lustrous color of aluminum.

The casting apparatus.

A description, or even an enumeration of all the apparatus, which have been suggested or put on the market would almost be impossible, as their number at present exceeds one hundred. Neither can special directions for use be given in describing the principles of each class of apparatus, as the author's experience is limited to but a few, and all directions necessary may be obtained from the manufacturer.

According to the manner in which the pressure is produced, all machines used for casting inlays may be divided into five classes. The pressure is produced in the different classes by, —

1. Gas,
2. Steam,
3. Direct contact,
4. Centrifugal force,
5. Vacuum.

An example of each class will be described, and the action of the pressure upon the molten metal and upon the mould, briefly explained.

1. Gas Pressure (Pneumatic force).

This class includes all machines using compressed gases, as nitrous oxid, carbon dioxid, or air. The eldest of this class, and at the same time the first machine for the purpose of casting inlays, was invented by Taggert (Fig. 96). In this

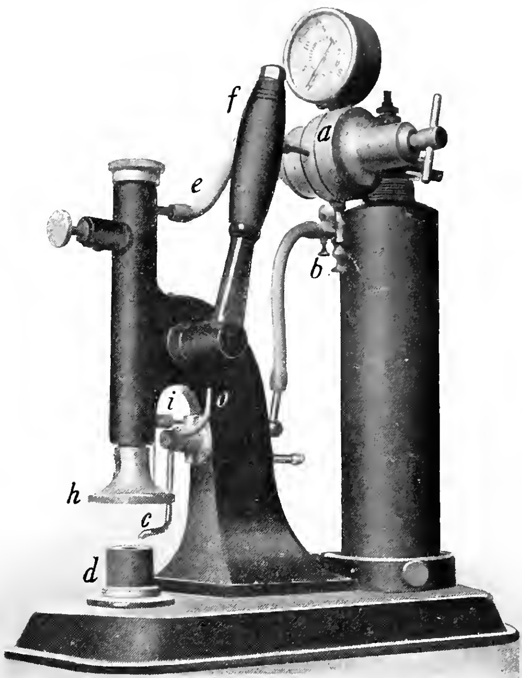

Fig. 96.

apparatus the compressed gas, nitrous oxid is not only used for the production of pressure in casting, but also as a flame to melt the metal. From the cylinder the gas flows through the reduction-valve (*a*) to the stop-cock (*b*), then through a rubber tube to the burner (*c*). The flame strikes the sprue-gate of the mold (*d*), where the metal to be fused is placed. By regulating the reduction-valve and observing the gage, the pressure deemed necessary in each case, is set before casting. When the gold is sufficiently heated, the lever (*f*) is quickly pressed down. The cam (*i*) pressing against the arm (*o*), turns the burner aside and extinguishes the flame, at the same time permitting the gas to pass from the valve (*a*), at the pressure perviously determined, through the tube (*e*) to the head (*h*). Five small holes in the middle of the under surface of the head serve to admit the gas to the mold, while a packing pressing on the edge of the casting-ring prevents escape.

In all machines of this class, the action taking place in the mold is the same. The gas in pressing upon the surface of the molten metal drives it into the mould. The gold in turn compresses the air contained in the cavity of the mold, thereby forcing the latter into the porous investment.

In regard to the effective pressure in the mold, Price says: "When the pressure is obtained from gas or air it is equal to the cross section area of the inlay or mold, not the gate or sprue, in fractions of a square inch divided into the pressure per square inch of the gas. For example, if the cross section area of the inlay is $^1/_8$ of an inch square, it will be $^1/_{64}$ of a square inch, and the pressure 16 pounds per square inch, the effective pressure will be $^1/_{64}$ of 16, or $^1/_4$ of a pound, less the back pressure of the gas retained in the investment behind the gold, and the leakage of the pressure around the gold, for if the pressure can get away through the investing material easily from behind the gold, it can easily get past around it in the same way; which means that there would be considerably less pressure than $^1/_4$ pound, depending largely on the compactness of the investing material and the leakage of the closing device over the molten gold. The writer believes

the effective pressure under the above conditions to be less than $^1/_8$ of a pound actual pressure."

It becomes evident from the above observations, that the action of the pressure in machines of this class must be rapid and intense, to prevent the penetration of the gas into the investment. Another fact to be borne in mind is, that the pressure indicated by the gage does not correspond to the pressure in the mold, as there is always more or less leakage through the packing between the head and the ring of the mold.

2. Steam Pressure.

"Solbrig's Pliers" are the eldest machine of this class. Upon one of the beaks, the mold is placed, while the other is constructed in the form of a shallow cup with an internal diameter corresponding to that of the ring of the mould. The cup is filled with sheets of asbestos (Section, Fig. 97), which

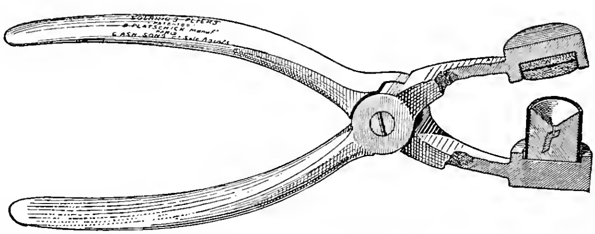

Fig. 97.

are moistened before casting. The gold is fused directly upon the mold. When the metal is sufficiently heated the pliers are closed, whereupon the steam generated by the heat in the moist asbestos, drives the gold into the mold. The simplicity of this principle makes the construction of an inexpensive apparatus possible. In Europe this is the type of machine most used. Numerous machines of this class are now on the market. The action taking place in the mold is the same as in the first class. The pressure can not however be determined, as it is dependent upon three variable factors, the amount of moisture contained in the asbestos, the temperature of the metal and lastly upon the adaptation of the asbestos packing to the edge of the ring of the mold.

The pressure however varies in direct proposition to the size of the casting. "A pressure gauge and the regulation of the pressure are quite superfluous, since the pressure is regulated automatically by the change of the factors which enter into the formation of steam. Thus, for a small inlay, owing to the small amount of metal, and the restricted quantity of moistened asbestos employed, we have less pressure than for the casting of a large plate, for which we employ a comparatively large mass of fused metal, and large asbestos discs for the production of a greater volume of steam. The pressure thus obtained varies between two and three atmospheres."*)

3. Pressure by Direct Contact.

Though probably not the eldest, one of the simplest machines of this class is that of Biber (Pforzheim). It con-

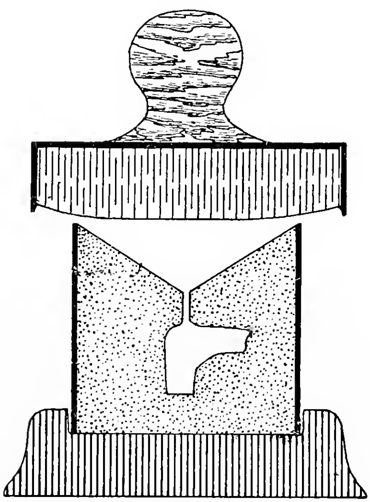

Fig. 98.

sists of a metal foot-plate supporting a mold of the usual form (Section, Fig. 98) and a loosely fitting cover filled with moldine. The metal is fused upon the mold and pressure exerted on the wooden knob of the cover. The pressure in

*) O. Solbrig, Ash's Quarterly Circular, Jan. 1910.

the mold depends upon the force used, and upon the softness of the moldine. In contradistinction to class I and II, the pressure does not penetrate the investment. The force must be applied quickly, as the metal coming into contact with the cold moldine solidifies rapidly. Solbrig*) claims that "the moisture contained in the substance employed (moldine) is the chief source of the pressure, and for this reason this kind of press must be put in the class of steam pressure apparatus."

4. Centrifugal Force.

But few machines of this class have appeared upon the market, the first was the Jameson machine (Fig. 99). This

Fig. 99.

consists of a circular casing attached to a solid iron base. The casing is divided by an asbestos-covered plate into a lower closed compartment, containing a spiral spring and a flywheel, and an open compartment above, containing the casting appliance proper. A vertical axle, to which below are attached the spring and the fly-wheel, carries at its upper end short arms,

*) O. Solbrig, Cast Metals in Dental Art, Asch Quartly, Jan. 1910.

with movable holders for the flat crucibles and for the molds. In casting, but one mold is used, the other serving as a counterweight. Owing to the horizontal position of the mold, a flat crucible lying opposite the sprue gate is used. A large Bunsen burner, for heating the mold, projects through the asbestos plate. The walls of the casing prevent the loss of gold, if spilled during casting. The process of casting with this machine is the following: By turning the arm 8—12 times, depending upon the amount of gold used, the spring is wound up. The brake *a* is then set as soon as the mould is over the opening of the Bunsen burner. The proper angle which the arm and holder should make to prevent spilling, is dependent upon the tension of the spring and the amount of gold used. After rotation has begun the holder again straightens out. When the mold is sufficiently hot, the gold is melted and the brake released. By centrifugal force the gold is thrown into the sprue-gate and into the mold.

As the writer prefers in most cases to use pure gold for inlays, and as the crucibles withstand a much higher heat than the investment, he employs oxygen in connection with illuminating gas to melt the gold more rapidly. The ordinary blow-pipe is used, the tube for the air being connected with the reducing valve of the oxygen cylinder (Fig. 100). This method is cheap and efficient, and is of great service in soldering platinum bases in porcelain work.

On the subject of pressure in the mold Price*) says: "With a centrifugal machine the actual effective pressure is the weight of the mass of molten gold, for our purpose irrespective of its shape, multiplied by the square of the velocity of the gold in feet per second, divided by the the radius in feet (not diameter) of the circle it moves in, divided by 32 to change poundal units to pounds pressure.

For example, if $^1/_2$ ounce of gold, which is $^1/_{24}$ pound troy, is revolving at the rate of ten revolutions per second, which is 600 per minute, in a circle of a diameter of ten inches, the velocity in feet is 10 (diameter) $\times$ 3,14 $\times$ 10 (revolutions) $\div$ 12 (inches) $=$ 26,17 feet per second, and the pressure

*) Items of Interest May 1908.

$^1/_{24}$ pound multiplied by 26,17 squared (the velocity), divided by $^5/_{12}$ (the radius in feet) divided by 32 = 2,14 pounds actual pressure on the inlay,"

$$\frac{1}{24} \times 684,86 \times \frac{12}{5} \times \frac{1}{32} = 2,14\ .$$

"If the revolutions are twenty times per second, which is 1200 per minute, the actual effective pressure is 8,56 punds,

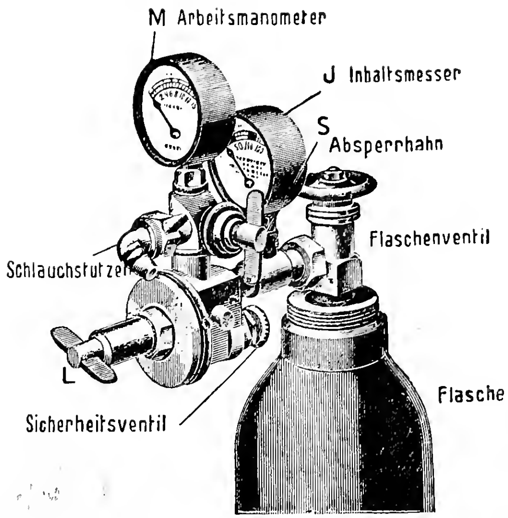

Fig. 100.

or if only five revolutions per second 0,53 or $^1/_2$ pound. Remember the pressure increases as the square of the velocity. If this pressure is on an inlay $^1/_8$ inch square ($^1/_{64}$ square inch) it is equal

at 5	revolutions per second to	$34^1/_4$	pounds per square inch
at 10	,, ,, ,, ,,	137	,, ,, ,, ,,
at 20	,, ,, ,, ,,	548	,, ,, ,, ,,

and without decrease for back pressure or leakage as in the case of a gas pressure. If an ounce of gold is used instead of one-half ounce the pressure is double the above."

5. Pressure Produced by Vacuum.

This method was first suggested by Frink*). But few machines of this class have been constructed; of these the "Elgin Vacuum Casting Appliance" is probably the most perfect (Fig. 101). This machine consists of an iron tank containing an exhaust pump. Attached to the tank are a gauge and an

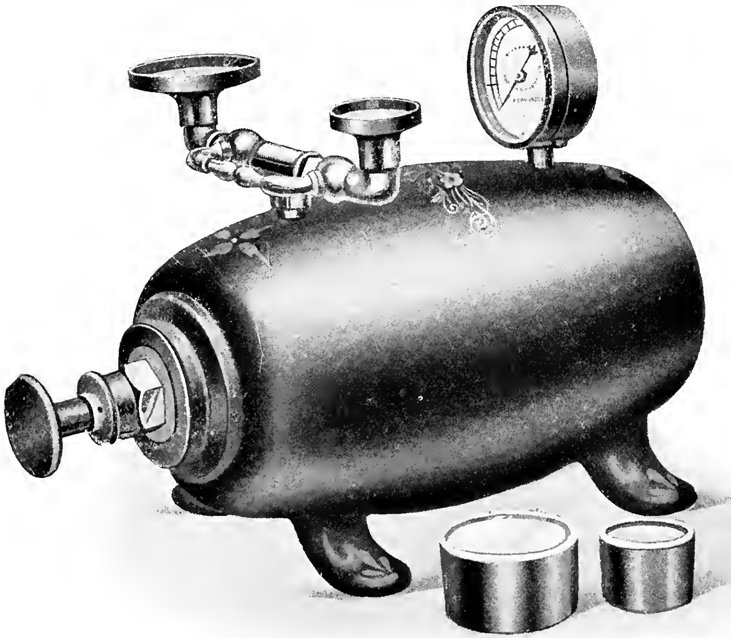

Fig. 101.

arm with two stop-cocks and two brackets of different size. Before casting, the tank is exhausted until the gauge shows a pressure of 15 units. The ring of the mould must be in absolute contact with the bracket. This is tested by opening the stop-cock. The gage should fall gradually without any hissing noise. When the gold, fused upon the mold, is sufficiently heated, the cock is opened. The metal is forced into the mould by atmospheric pressure.

*) Dental Cosmos Feb. 1908.

The actual pressure upon the inlay at the moment of casting may approximately be determined as follows. The atmospheric pressure at thirty inches is 14.7 pounds to the square inch. The gauge of the machine shows a negative pressure of fifteen inches, that is, one-half of the normal pressure or 7.35 pounds to the square inch. Assuming the cross sectional area of the inlay to be $^1/_8$ of an inch square, or $^1/_{64}$ of a square inch, the effective pressure will then be 7.35 $\times$ $^1/_{64}$ or 0.115 pound. No allowance is therein made for leakage between mold and bracket, or for the pressure penetrating the investment in advance of the gold. The actually effective pressure upon the inlay is therefore less than 0.1 pound.

With proper manipulation, successful work can be done with machines of all the classes described above, and yet, the ideal machine has still to be constructed. Price has suggested such an apparatus, in which the pressure can be accurately controlled and the temperature of the fused metal easily determined; a centrifugal casting machine, driven by an electric motor, heated by electricity, and having a pyrometer attachment. The cost of a machine of this kind would however be very great. For experimental work such an apparatus would be of the greatest value.

After casting, the mold should be gradually cooled. Sudden chilling in water, though advocated by many, is liable to cause distortion through unequal contraction of the metal. When the mold is cool, the inlay is removed from the investment and cleansed with a small brush. The dead-head is nipped off at about an eight inch from the inlay.

Combination Inlays.

A combination of gold and porcelain in making inlays has been advocated by a number of writers. The use of such inlays is confined to the labial surfaces of anterior teeth. The results, in regard to adaptation are not as satisfactory as those obtained with all-metal inlays. In solidifying and in cooling, a cast inlay is constantly under pressure, if then the inlay is annealed, as it is in fusing the porcelain, it will undoubtedly change in form. Compared to a porcelain inlay, its esthetic

qualities are less satisfactory. The combination of a gold inlay and silicate cement appears still more unesthetic.

Combination inlays are made by cutting away a part of the metallic inlay, and restoring the form with porcelain. To avoid the difficulty of cutting the metal, the part to be restored with porcelain is removed from the wax model. This may be done with a bur, a sharp carving instrument, or with Roach's

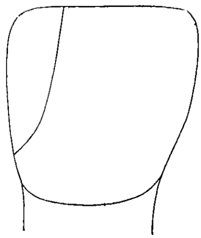

Fig. 102.

suction-carver. The porcelain is either fused directly onto the roughened inlay, or an impression is taken, and the porcelain with the matrix, cemented onto the roughened inlay. In this method a line of metal is alway present between the porcelain and the margin of the cavity.

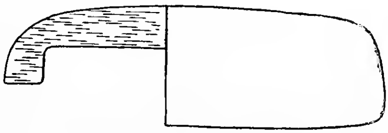

Fig. 103.

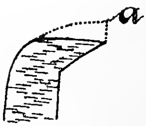

Fig. 104.

The few combination inlays that the writer has set, were made so, that no gold showed between the porcelain and the enamel margin. As an example a proximal cavity involving the incisal angle has been chosen (Fig. 102). The general cavity-preparation is similar to that shown in Plate XIII. The wax-model is made in the mouth, and into the surface, visible in the finished inlay a cavity is cut (section Fig. 103). At the cutting edge, where the metal should protect the porcelain, the wax is extended slighty beyond the normal length (section Fig. 104). This obviates the difficulty of carv-

ing a feather edge upon the wax-model. After the porcelain has been fused onto the inlay, the excess (*a*, Fig. 104) is *carefully* removed with a disk, so that no metal may be visible in the mouth.

The inlay is cast in 22 kar. gold and tried in the cavity. It is then removed and the walls of the cavity which are to lie in contact with the porcelain, are covered with a piece of No. 40 gold-foil. The foil should lie perfectly flat, without any folds, and should extend slightly under the inlay (*f*, Fig. 105

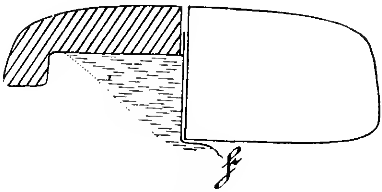

Fig. 105.

At other points upon the margin of the cavity, small pieces of the same foil are laid. This raises the whole inlay out of the cavity a distance equal to the thickness of the foil. Later, when the matrix has been stripped from the porcelain, the inlay again fits into place, and the porcelain lies in absolute contact with the walls of the cavity.

After the foil has been properly placed, the inlay is introduced into the cavity and firmly held in position. Inlay wax is then pressed into the cavity of the inlay and against the matrix (Fig. 105) which is thereby quickly and accurately adapted to the margin of the cavity of the tooth. The difficulties often encountered in removing the inlay with the matrix from the cavity, can be overcome only by patient and careful manipulation. In order to facilitate the removal, the sprue on the inlay should be left sufficiently long, so that it may be firmly grasped with a pair of tweezers. The inlay and matrix are then invested, and the contour restored with Jenkin's Porcelain Enamel.

Another method of combining gold and porcelain in an inlay, is to make the porcelain part first, and then to com-

plete the metallic part of the inlay. The writer considers this method practicable only when large pieces of porcelain or whole facings can be used (Plate VIII).

The surface of a metallic inlay, after being properly roughened, may be covered with a layer of porcelain. This, however, is applicable only to surfaces not exposed to the force of mastication.

Chapter XI.

Setting the Inlay.

After the inlay has been cast, all adherent particles of investment material are removed with a stiff tooth-brush and water. A perfect inlay at this stage should be an exact reproduction of the wax model. It should have smooth surfaces with sharp margins and well defined angles. Before the inlay is finally set with cement, it must be fitted, burnished, and undercut or roughened.

Fitting the Inlay.

The excess metal, or dead-head is cut off, leaving a stump about an eight of an inch in length attached to the inlay. In trying the latter in the cavity, this stump, when not situated at the contact point, offers a convenient hold for the tweezers, while in roughening and undercutting the inlay, it can be firmly grasped with a pair of flat-nosed pliers. In cases where the sprue has been placed at the contact point, the stump is cut somewhat shorter. While repeatedly attempting to seat the inlay in the cavity, the sprue-stump is gradually ground down, until with some slight force the inlay is brought into its proper position. The contact point then presses firmly against the adjoining tooth. The inlay is thereupon removed from the cavity and the proximal surface finished and polished with cuttlefish disks. Care should be taken to touch the contact point as little as possible.

An inlay, perfect in form, can be introduced into the cavity without difficulty. If the inlay does not go into place easily, the reason must be sought, and the cause removed. If necessary another inlay should be made. The fact should always be borne in mind, that an inlay requiring much fitting can never be considered a perfect piece of work. If a faulty inlay

is set, the operator, and not the inlay process, is responsible for any subsequent failure.

An inlay may be faulty from several causes. The sources of error are: an inaccurate impression, improper investment, and imperfections in casting. The impression was distorted, if an inlay which had been properly invested and perfectly cast, as shown by its smooth surfaces and sharp margins, cannot be introduced into the cavity. Either the wax model had changed in form, or the thin anchorage extenstions had been bent in removing the model from the cavity. If such an inlay cannot be forced into the cavity, it is far better to make another, than to attempt to remedy the difficulty by grinding. When only the extensions are bent, the inlay is firmly pressed into the cavity with a large burnisher and the extensions driven into place by means of a smooth plugger upon which an assistant taps with a mallet.

Small rounded projections, occurring in three distinct forms upon the surface of the inlay, point to the presence of bubbles in the investment. A bubble directly upon the surface of the wax model results in a hemispherical projection on the inlay. If, however, a very thin layer of investment separates the bubble from the wax model, the pressure in casting will break down this wall, and the projection will appear as an almost perfect sphere upon the inlay. If a number of such bubbles lie together, the pressure will destroy not only the layer of investment separating the bubbles from the wax model, but also the walls between the bubbles. This gives the projection upon the inlay an irregular form. The spherical form can easily be removed with a sharp instrument. The other forms can be removed only by grinding. If present in greater numbers, especially at or near the margin of the cavity, they are apt to make the inlay worthless.

An imperfectly cast inlay may be faulty in three respects; it may show either a granular surface, rounded margins, or blow-holes. The granular surface results from the use of superheated metal in casting. If the mould made of investment material had the same physical properties as one made of metal, overheating the gold would have no influence upon

the exact size of the inlay. Overheated metal (*b*, Fig. 106) cast in a metallic mold (*a*), shows a smooth surface with slight depressions. In number, the latter depend on the degree to which the metal has been overheated, and upon the mass of the metal itself. The size of the casting is in no way altered. If, however, an investment material is used in making the mold,

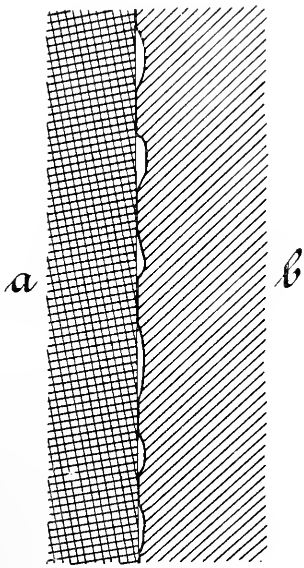

Fig. 106.

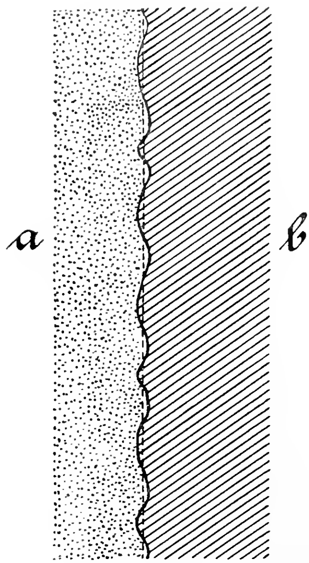

Fig. 107.

the high heat of the metal (*b*, Fig. 107), destroys the smoothness of the walls of the mold (*a*), thereby producing slight elevations and depressions which give the surface of the metal a granular appearance. The size of the casting is somewhat increased. It is not necessary to call further attention to the significance of this fact in casting inlays.

The damage done by the overheated metal is sometimes confined to the wall lying opposite the sprue-gate. In such cases, the metal though not greatly overheated, is sufficiently hot to disintegrate the surface of the investment where it first strikes the wall of the mold. The current of the molten metal then erodes the surface at this point. It is preferable, there-

fore, that the point opposite the sprue-gate should lie upon a smooth wall, and not near the margin of the inlay, or near the angles of an anchorage extension. The sharp angle of the occlusal step at the axial wall, is therefore an unnecessary source of danger which should be avoided by sloping this part of the cavity, as shown in Plate I. As the point of attachment is determined by the contact point, the direction of the current of metal may be varied, by altering the angle at which the wax model is set upon the sprue.

Overheating the metal in casting, often makes the inlay worthless. Especially is this true of inlays having complex anchorage extensions; as for example, a proximal inlay with transverse fissure anchorage in a lower molar (Plate I). At the angles, where the longitudinal and transverse fissures cross each other, the current of overheated metal distintegrates the investment and carries away the loosened particles. Under such circumstances, the finished inlay cannot possibly fit into the cavity.

The only means of fitting an inlay, with a partially or totally granular surface, is by careful grinding. A perfect result is, however, rarely obtained. If the defect is confined to a small area, the following method may be tried. The inlay is placed in the cavity and rocked back and forth under pressure. Upon examining the under surface of the inlay, burnished spots will be found which mark the places where the inlay rests upon the tooth. The amount of metal to be removed must be determined beforehand, as a second attempt to locate the point of difficulty by rocking the inlay will usually be unsuccessful, the burnished spots not being recognizable upon the ground surface of the metal. If further efforts to fit the inlay are to be made, the walls of the cavity should be coated with coloring matter. The inlay can then be repeatedly tried in the cavity, and the places marked, ground off. This procedure cannot, however, be recommended by the writer, as the result always is an imperfect piece of work. In the time spent in attempting to fit a faulty inlay, another wax model can be made. And the finished inlay will then be far more satisfactory.

Rounded margins (Fig. 108) are the result of an insufficient heating of the metal in casting. Whether the faulty inlay can be used or not, depends upon the degree of the defect and upon the position of the cavity to be filled. An inlay with *slightly* rounded margins, in a simple, easily accessible cavity, can by burnishing, be perfectly adapted to the margins. On the other hand, a proximal inlay with edges equally rounded is worthless, as the cervical margin of the cavity is not sufficiently accessible. A proximal inlay must therefore always be perfect in this respect.

For the purpose of adapting the rounded edges of the inlay to the margins of the cavity, the corrugated burnisher,

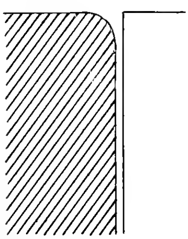

Fig. 108.

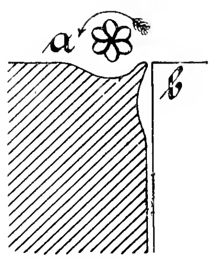

Fig. 109.

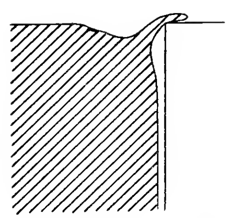

Fig. 110.

also called tomato-burnisher, is the most suitable instrument. The burnisher, rotating in the direction of the margin (*a*, Fig. 109) throws up a ridge at this point. The purer the gold, the more easily can this be accomplished. If the extreme edge of the enamel is at right-angles to the surface of the tooth, there still remains a space at *b* (Fig. 109) after the burnishing has been completed. Further burnishing will not obliterate this space, but will only force the metal over the edge of the enamel (Fig. 110). If the margin of the enamel is bevelled (Fig. 111), the gold can be more easily adapted (Fig. 112). Adapting the slightly rounded edges of a faulty inlay by burnishing, is therefore permissable only in simple cavities with bevelled enamel margins. Upon an occlusal surface, where the walls of the cavity have been prepared at right-angles to the surface, such a procedure cannot be recommended, as at this point a perfect adaptation, extending well towards the

floor of the cavity is absolutely essential. An inlay with rounded margins should, never be set in an occlusal cavity unless deep fissures have been carved into this surface.

Blow-holes can be repaired only by filling the defect with gold foil. If the hole has resulted from the presence of foreign matter, the inlay should be boiled in acid. The form of the defect is usually such, that it offers ample retention for the filling. Should this not be the case, undercuts must be made in the inlay.

When the inlay fits into the cavity, the bite should be controlled. If the inlay is too high, this may be corrected

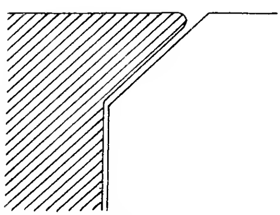

Fig. 111.

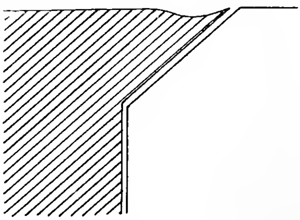

Fig. 112.

by allowing the patient to bite upon tracing-paper, and grinding away the places marked until the articulation is correct. The edges of the inlay are then burnished against the margins of the cavity, upon the occlusal surface with a corrugated burnisher, and on the proximal surface with a flat hand-burnisher.

In removing the inlay from the cavity, care must be taken to avoid injuring the edges. Occluso-proximal inlays should be removed by placing the point of an instrument below the contact point and pressing in the direction of the occlusal surface. In simple cavities it is often difficult to remove the inlay without injuring the edge. This danger may be avoided by leaving the stump of the sprue attached to the inlay until after it has been burnished. As the sprue-stump interferes at certain points, special attention should be paid to these in reburnishing the inlay after it has been introduced into the cavity, and before the cement has set.

Undercutting and Roughening the Inlay.

The inlay, at this stage, is ready to be undercut or roughened. Simple inlays, firmly held with flatnosed pliers by the sprue-stump, may be easily undercut with a fine hand-saw. If the sprue-stump has previously been cut off,

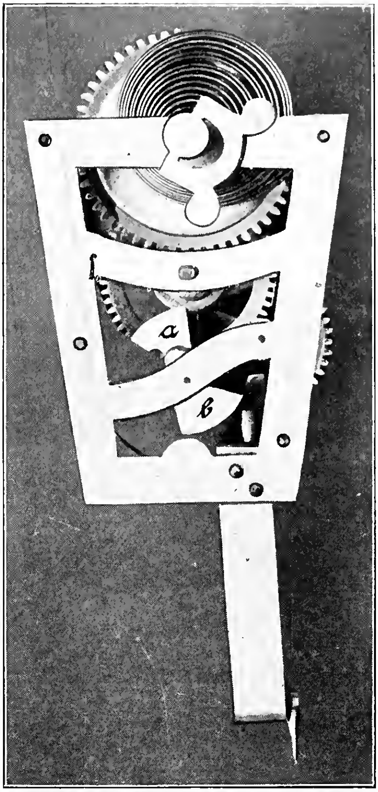

Fig. 113.

or if the inlay is of complex from, it must be held in the fingers, and the undercuts made with a small knife-edged stone, or a crown saw in the dental engine. The rotary saw, though useful, cannot be recommended, it being liable to jump over the edge of the inlay and injure the fingers. As cutting the metal always leaves feather-edges, these must be ground

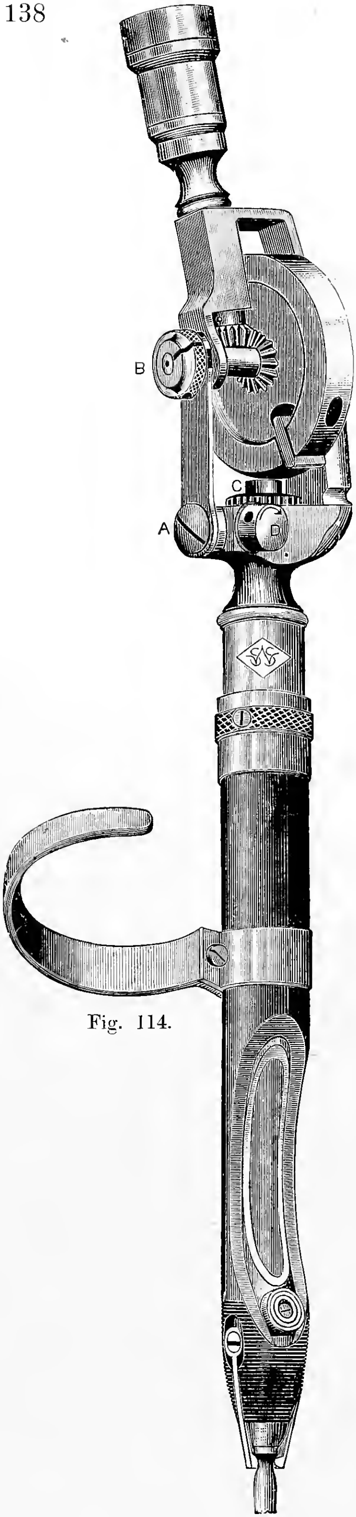

Fig. 114.

off from the margins of the undercuts, and the inlay again tried in the cavity. If the size of the inlay permits, it is always preferable to make the necessary undercuts in the wax model.

The best instrument for roughening inlays is, in the opinion of the writer, the mechanical engraving apparatus shown in Fig. 113. It is known in the German jewellers' trade, as the dot-engraving apparatus Matador (Gravier-Punktierapparat Matador). It consists of a clockwork which drives a hinged weight (*a*), and a counterweight (*b*). Only the former strikes the end of the engraving instrument. As the weight is usually not heavy enough, a small piece of lead must be screwed onto the upper surface. Owing to the fact that the weight is hinged, the blow given by this instrument is perfectly "dead". The Bonwill mallet*), depending for its action upon an immovable cam, carried on a wheel and stricking the end of the instrument at each revolution, gives a short, sharp blow. As the gold, in this case, has not sufficient time to escape, the surface is but slightly roughened. With the Bonwill mallet the point of the instrument, should be small and very sharp, while with the en-

*) G. S. Hersey, Dental Cosmos Nov. 1906, p. 1167.

graving apparatus the point should be ground in the form of a half-round chisel.

At points where nothing has been removed from either wax model, inlay, or cavity wall, the inlay is roughened by blows at right-angles to the surface (Fig. 13). But where the space between inlay and cavity wall permits, the step-like projections (Fig. 14), made be applying the roughening instrument obliquely, are to be preferred.

In the tooth, the undercuts should be placed and shaped as has been described under "Retention" (Chaps. III and IV). The removal of the last traces of caries, or of the material filling the natural undercuts, often makes further undercutting unnecessary.

The Cement.

Before discussing the subject of setting the inlay, the requisite qualities of a cement for this purpose will be mentioned. The material used as an inlay cement should,

1. be so fine grained, that it forms a very thin film under pressure,
2. possess great compression strength,
3. neither expand nor contract during the process of setting,
4. be impenetrable to moisture,
5. possess hydraulic qualities,
6. set sufficiently rapidly,
7. be as insoluble as possible, and
8. possess adhesive qualities.

Of these qualities the first four are essential, while the last four add to the value of the cement.

1. Experiments to determine the relative value of cements, in regard to all the above mentioned qualities, have not yet been made. Joseph Head (Philadelphia) published an article*) upon thickness of the cement line, and as the result of his experiments, tabulated below, comes to the following conclusions. The thickness of the cement layer depends upon the size of the cement grains. Great, or prolonged pressure changes the result but little.

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*) Tests on the Inlay Cement Problem. Dental Cosmos, July 1905.

	8 pounds[1]), 1 Min.	8 pounds until set.	25 pounds, 1 Min.	25 pounds until set.	50 pounds, 1 Min.	50 pounds until set.	100 pounds, 1 Min.	100 pounds until set.
Harvard (coarse)	.00243[3])	.00249						
„ Inlay (Jenkins)	.00168	.00171						
„ Special (Head)	.00156	.00152	.00143	.00125	.00106	.001175	.00114	.00089
Ames Inlay . . .	.00109	.00096	.000886	.000882	.000725	.000702	.00079	.000604
Ash.	.00229							
Harvard Pulv.[2])	.0003[3])	.00027						

[1]) Pressure on $^1/_4$ square inch.

[2]) Harvard Pulv. is a Harvard cement "pulverized in an agate mortar until the grit was imperceptible to the teeth".

[3]) Thickness of film, in fractions of an inch. (The thickness of No. 30 gold foil is about .0003 in.)

2. Experiments to determine the compression strength of the various oxyphosphate cements, have not been made.

3. und 4. The second table, compiled from the article of G. C. Poundstone*) (Chicago), shows the structure, the expansion, and the permeability of a number of cements. The names of the preparations are, however, not mentioned.

5. A hydraulic cement is one which sets under water. It has been claimed, that oxyphosphate cements are not hydraulic, that they are only apparently so, owing to the rapidity with which they set. Only by practical tests can this question be decided.

6. The rapidity with which a cement should set, depends upon personal preference and upon the difficulty of introducing the inlay into the cavity. With every cement, the time of setting can be regulated by varying the relative amounts of the liquid and the powder, or by using powders containing more or less coloring matter. Some manufacturers recommend the use of a retarding "flux".

7. All cements are more or less soluble in the mouth. The solubility of any of the standard preparations is, however, not so great as to endanger the durability of a perfectly adapted inlay.

8. In the retention of an inlay, other factors are far more important than mere adhesiveness of the cement. While

*) The Cement Problem in Inlay Work. Cosmos, July 1905.

Cement	Large Granules		Medium Granules		Fine Powder	Bubbles in setting	Thickness of Cement after setting under 25 pounds pressure		Expansion	Subsequent change	Cement, set under pressure between etched cover-glasses, and placed in eosin. Complete penetration.
	Relative number	Size of largest	Relative number	Average size	Relative amount		15 min.	24 hrs.			
A.	Few	35 μ[1])	Many	8—15 μ	Small	Many	21 μ	21 μ	0 μ	Slight Expansion	7—10 days
B.	Few	50 μ	Few	10—15 μ	Large	Many	23 μ	43 μ	20 μ	None	4—5 days
C.	Few	50 μ	Many	7—15 μ	Small	Very few	22 μ	44 μ	22 μ	None	4 days
D.	Very few	56 μ	Few	12—18 μ	Very large	Very many	24 μ	25 μ	1 μ	Slight increase in expansion	7—10 days
E.	Very few	25 μ	Very many	10—15 μ	Small	Few	27 μ	27 μ	0 μ	None	But little in 14 days
F.	Few	56 μ	Many	16—30 μ	Large	Few	30 μ	34 μ	4 μ	None	5—6 days
G.	Few	46 μ	Many	18—22 μ	Large	Very few	32 μ	42 μ	10 μ	None	5—6 days
H.	Few	40 μ	Many	5—20 μ	Small	Many	26 μ	27 μ	1 μ	Slight increase in expansion	3 days
I.	Very few	27 μ	Very many	10—15 μ	Small	Few	31 μ	35 μ	4 μ	Slight increase in expansion	But very little in 14 days
J.	Very few	25 μ	Very many	8—15 μ	Large	Few	25 μ	33 μ	8 μ	Slight increase in expansion	10—14 days

1) μ, a micron, the millionth part of a meter, or $\frac{1}{25400}$ of an English inch.

cement is still very soft, it undoubtedly is "sticky", but after it has set, it does not possess any adhesive qualities. The fact that old cement can often be removed only with difficulty from the walls of the cavity, does not prove the adhesiveness of cement, but proves that the cement was of such a character, that it could adapt itself to the most minute inequalities upon the surface of the dentine. The tests made to determine the adhesiveness of cements are of little practical value, as they do not reproduce the conditions existing in the cavity of the tooth, while in the mouth. Poundstone tested the cements A to J, by cementing together ivory blocks whose surfaces, 60 square millimeters in area, were roughened with a vulcanite file. "They were kept dry for 24 hours, when they were pulled apart." The average force required varied from $23^1/_2$—$59^1/_4$ pounds. From a practical stand point the following tests are of interest. "Repeated tests were made by cementing the blocks together and keeping them in saliva in the incubator at 37 ° C, but in every instance the force necessary to separate them was so slight that it was impossible to measure it with any degree of accuracy. These were flat surfaces, with force applied perpendicular to the surface. When force was applied parallel with the surface, i. e. when an attempt was made to slide the blocks apart, considerable resistance was met with, the film of cement apparently interlocking into the uneven surfaces of the blocks on either side."

The constant improvements made by the manufacturers, make it impossible to state which cement most completely fulfills the requirements mentioned above. Each operator must be guided by his own experience, in selecting an inlay cement. Only standard preparations should be considered.

Drying the Cavity.

The use of the rubber dam is not necessary in setting an inlay. The process occupies but so short a time, that the field of operation can usually be kept dry very easily. In two to three minutes after the first drying of the cavity, the inlay may safely be exposed to the saliva, if a hydraulic cement, mixed by an assistant, has been used.

To keep the tooth dry, the usual appliances are employed. As these are well known they need not be described in detail. Cotton rolls, or napkins in connection with ordinary or specially constructed clamps, tongue-holders, or mouth-specula are most commonly used. The saliva-pump, also is of great value.

The tooth is cleansed with a stream of water, and the cotton rolls put in position. The cavity is then dried and disinfected. For this purpose a variety of medicaments are used. The method of the writer is the following. A pledget of cotton saturated with a solution of equal parts of sodium hypchloride ($NaClO$) and potassium hypobromide ($KBrO$) is placed in the cavity. If the dentine is sensitive, the wet cotton is warmed over the flame of an alcohol lamp. With a broach, around which a few fibers of cotton have been wrapped, dilute sulphuric acid is added until the reaction ceases. The reaction which take place, consists in a liberation of chlorine, bromine and oxygen. As these are present in their nascent state, they have a powerful germicidal action, thus thoroughly disinfecting the tooth. The cavity is then again flooded with the above-mentioned alkaline solution, to neutralize every trace of the acid, and is dried, without being again rinsed out with water. Even the most sensitive dentine can be disinfected, if the solutions are used in the order mentioned, and carefully warmed. Experience has shown, that as a result of this procedure the cement forms a strong attachment, probably owing to the the action of the acid in roughening the surface of the dentine.

Regarding the much debated question of thoroughly drying the cavity, the writer, from practical experience, believes a dry surface to be not alone desirable but absolutely necessary for a perfect union between cement and dentine. W. V. B. Ames*), however, states: "I believe that it is thoroughly impractical and unscientific to expect to be able to flow a proper mix of cement to this desiccated surface and have it give the maximum of adhesion, *because* this cement will simply bridge across the microscopical irregularities of this surface, and the tubuli — if you please — without *knitting* into them, as the

*) Dental Summary Vol. XXV, No. 1 p. 71.

cement *must* to give maximum adhesion. Granting that thorough cleansing and superficial desiccation is desirable, I will claim that we should then thoroughly moisten this surface with the liquid of the cement we are about to use, or possibly better, some plain syrupy phosphoric acid, and after being satisfied that this has caused the displacement of air in all inequalities of the surface, all visible surplus of this should be removed by air blast or absorbents." Only by making a series of comparative tests, can this question be decided. The writer, however, believes, that the thinly mixed cement, under the pressure of forcing the inlay into place, can more readily fill out all minute depressions if these are empty, than if they have previously been filled with another fluid.

With absolute alcohol and hot air the cavity is dried. If the dentine is sensitive, the pledget of cotton saturated with alcohol is ignited and allowed to burn 5—10 seconds. After being extinguished, it is immediately placed in the cavity, and the alcohol partially evaporated with the hot air syringe. Thereupon the cotton is removed, and the drying of the dentine continued until its surface becomes white. After about a minute the whiteness disappears, proving that the dentine had been dried out but superficially, and that it rapidly regains its normal moisture. This is of advantage to the hydraulic cement in setting.

Setting the Inlay.

General directions for mixing the inlay cement cannot be given, as each preparation requires special handling, and this can only be determined by practical tests. With the cement mixed to the proper consistency the walls of the cavity are carefully covered. The dentine should be covered at every point, to avoid the danger of imprisoning air under the inlay. The air forms a cushion, which drives the inlay out of the cavity before the cement has set, or it may escape partially and leave a space between the inlay and the wall near, or at the margin of the cavity. The thin cement, to cover the walls of the cavity, is taken up on

the point of a spatula and dripped into the cavity if the tooth is in the lower jaw. If it is in the upper, the spatula is held before the opening of the cavity and the cement pushed in with a large ball-burnisher. With a smaller instrument it is then quickly spread over the surface of the dentine, and an additional quantity of cement introduced into the cavity. With a pair of tweezers, preferably those suggested by A. Guttmann (Berlin) for porcelain inlays (Fig. 115) as they prevent the inlay from escaping from between the points, the inlay is placed in the cavity. By alternately pressing with two

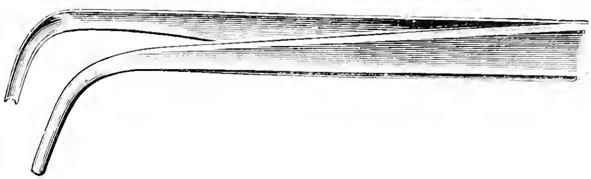


Fig. 115.

burnishers, the inlay is forced into place with a rocking motion (Taggart). This seats the inlay more quickly and dislodges the larger granules of cement more easily than steady pressure in one direction.

After the inlay is in position the margins are rapidly burnished and steady pressure is exerted for about one minute. With an explorer the margins are then examined. If at any place the inlay protrudes slightly, though this should *not* happen in a perfect piece of work, the cement, still somewhat soft, is removed at that point with a fine instrument, so that later the metal can be burnished against the margin of the cavity. As moisture can now no longer affect the hydraulic cement, the cotton rolls may be removed. The patient should be cautioned not to occlude tightly, as the cement only sets in 8—10 minutes. The surplus cement should remain in place until it has hardened.

Finishing and Polishing the Inlay.

When the cement has set, the excess is chipped off with a sharp instrument. This, by the way, would not be possible

if the cement were truly adhesive. With tracing-paper the bite is controlled. If it proves to be too high, — a serious matter if the inlay was of the proper height when previously tried in the cavity, — the place marked must be ground off with a small stone (Fig. 116), or with a plug finishing bur. Care should always be taken, when grinding near the edge of the inlay, to let the instrument rotate so, that the gold is forced against the margin of the cavity. For this reason, it is necessary to have left-as well as right-cut finishing burs on hand. The pear-shaped form is the most serviceable (Fig. 117). These instruments being small, confine there action to a limited

Fig. 116.

Fig. 117.

Fig. 118.

Fig. 119.

area. They cut more rapidly than the gem-points, as long as they are sharp. The double cone-shaped bur (Fig. 118) is used to restore the form of the fissures that has been destroyed in grinding the inlay. The margins of the occlusal surface are finshed with fine stones.

After the bite has been corrected, the margins of the proximal cavity should be examined. If the unpleasant discovery is made, that the inlay protrudes from the cavity, the edges must be ground down, preferably with spear-shaped finishing burs (Fig. 119). At accessible places a somewhat thicker form may be used, as this does not become dull so rapidly. As the metal should always be cut in the direction of the cervical margin, right- and left-cut finishing burs are required. In most cases it will be necessary to use them in the right-angle handpiece. Where there is no danger of injuring the contact point, sandpaper disks may be employed. Great care should be exercised in finishing the proximal margins, as there is always danger of dislodging the newly

set inlay by pressure upon this surface. It is better therefore, to postpone any extensive operation of this kind until a subsequent sitting.

The writer is not able to appreciate the beauty of a high polish, prefering a smooth but dull surface, which makes a metallic filling less conspicuous. The inlay is quickly polished by using rubber or moose-hide disks, and cloth strips with a mixture of carborundum flour and vaseline. The action is rapid and the effect very satisfactory.

Chapter XII.

The Metallic Inlay as a Bridge Abutment.

Owing to its massiveness and apparent strength, the metallic inlay has appealed to many as a means of anchoring bridges. Various forms of inlay bridge abutments have been suggested, but the majority of these fail when put to a practical test. Many men, therefore condemn the use of the inlay abutment. Nevertheless it remains a fact, that inlays have been used successfully for this purpose, and that if properly constructed in accordance with certain definite mechanical principles, they may certainly be used with safety in some cases.

It is not the intention of the writer to suggest still another form of inlay abutment, but only to describe the mechanical principles that must be taken into account in the construction of an inlay of this kind.

In explaining the stress and strain upon an inlay used as a filling, only the force of mastication was considered, while movement of the individual tooth was disregarded. This movement, however, becomes of prime importance in determining the form of the inlay abutment. To the mechanical factors to be considered in constructing an ordinary inlay, must be added that of movement of the tooth in three directions; bucco-lingually, mesio-distally, and vertically. The effects of these movements on inlay abutments situated in bicuspids and molars will be described in detail. For the sake of clearness, a bridge with but one inlay abutment has been chosen as an example. The inlay is placed in the second molar, while the other abutment consists of a shell-crown placed upon the second bicuspid. A square bar connecting the two, represents the bridge.

Bucco-lingual Movement of the Anchor Teeth.

Movement in the bucco-lingual direction will not endanger the anchorage as long as both abutment teeth move an equal

distance in the same direction. If, however, these teeth move unequally, or in opposite directions, both abutments will be strained to the same extent. If the molar is firm and the bicuspid is loose, the greater strain will be exerted upon the inlay in the firm tooth.

A loose tooth in moving, describes the arc of a circle whose center lies at the apex of the root. The crown, therefore, changes its angle and is displaced vertically and horizontally (Φ, *a*, *b*, Fig. 120).

Whenever the loose tooth changes its angle bucco-lingually in relation to the firm tooth, a torsional strain is exerted upon

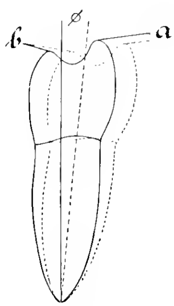


Fig. 120.

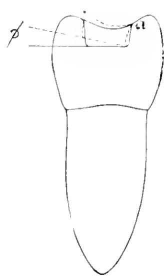


Fig. 121.

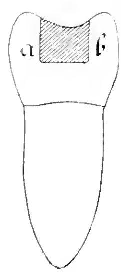


Fig. 122.

the connecting bar. The torsional force exerted upon the inlay is proportional to the angle of torsion (the movement of the loose tooth). It is, however, independent of the length of the bar. The effect of this force is to twist the inlay out of the shallow cavity upon the occlusal surface of the tooth (Fig. 121). The point *a* acts as a fulcrum. To counteract this force, a proximal cavity should be excavated with walls parallel to the long axis of the tooth (*a* and *b*, Fig. 122). This locks the inlay so that it cannot be dislocated by torsional strain.

The vertical displacement is slight (*a*, Fig. 120), as the tooth moves through but a small arc of a circle. The effect of this movement upon the inlay abutment, will be more fully described later.

The horizontal or lateral displacement (*b*, Fig. 120) of the loose tooth exerts a strain upon the inlay abutment pro-

portional to the length of the connecting bar, and to the force applied to the loose tooth. The lingual or buccal edge of the inlay acts as the fulcrum (*a*, Fig. 123). If the inlay is firmly anchored, there is a tendency to rotate the firm tooth. The mechanical action represents a lever of the first class, applied at right-angles to the long axis of the tooth.

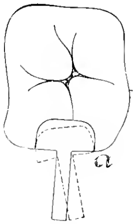


Fig. 123.

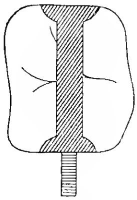


Fig. 124.

The mechanical principles upon which the anchorage of inlay abutments depend can most clearly and easily be explained by representing the tooth as a nut, and the inlay and connecting bar as the head and handle of a wrench.

If the wrench shown in Fig. 126 has sufficiently wide jaws, it will grasp a nut firmly when placed at right-angles to the

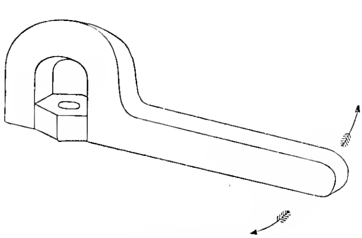


Fig. 125.

nut, as in Fig. 125. Applied to the abutment in question, this means, that if the inlay were extended across the occlusal surface and then at right-angles upon the distal surface of the tooth, the leverage exerted by the bucco-lingual movement of the loose tooth could not endanger the anchorage of the abutment (Fig. 124).

The best shape of inlay abutment for resisting the torsional strain and the force of the leverage produced by the lateral

movement of the loose tooth is one, which in the form of the wrench Fig. 126, extends over the mesial, occlusal, and distal surfaces of the tooth. On one of the proximal surfaces the margins *a* and *b*, Fig. 122, should be parallel. Special care

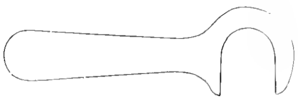


Fig. 126.

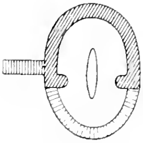


Fig. 127.

must be taken to make the surfaces *a* and *b*, Fig. 136, representing the jaws of the wrench, parallel to one another.

Without going into detail, the action of a few types of

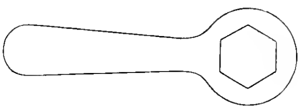


Fig. 128.

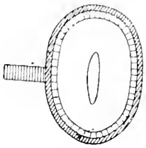


Fig. 129.

bridge abutments in resisting *lateral displacement* of the other end of the bridge, may be mentioned. No special comment on the action of the square post, is necessary in this connection.

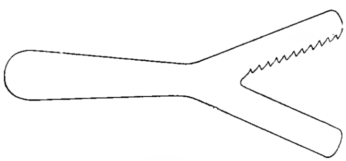
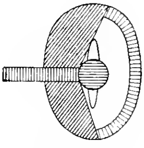


Fig. 130.



Eig. 131.

The wrench Fig. 126 applied parallel to the nut, illustrates the principle upon which the Carmichael abutment depends in resisting lateral displacement of the other end of the bridge (Fig. 127). The wrench Fig. 128 shows the principle involved in the use of shell-crowns and banded pivot-teeth (Fig. 129). Even the alligator wrench (Fig. 130) may represent the proto-

type of a serviceable inlay abutment, if the latter is constructed with a strong post (Fig. 131), and provided with a hook-anchorage (p. 30).

Mesio-distal Movement of the Anchor Teeth.

In this direction also, a tooth moves in an arc of a circle whose center is situated at the apex of the root. The slight variation occuring in the molars may be disregarded. The diagram Fig. 132 shows two pointed blocks representing a

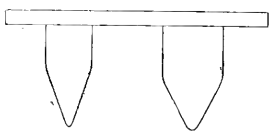


Fig. 132.

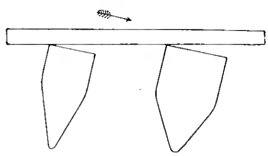


Fig. 133.

bicuspid and a molar across which a bar has been laid. In moving, the blocks describe circles about their pointed ends. If the bar is moved distally, both teeth, tipping in this direction, support the bar only on their mesial edges (Fig. 133). When moved in the contrary direction, the bar bears only upon the distal edges of the teeth (Fig. 134). If instead of a bar, a double-

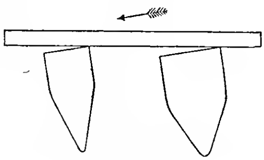


Fig. 134.

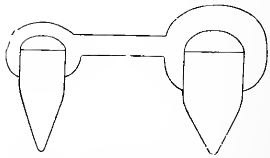


Fig. 135.

ended wrench with long jaws, is placed upon the blocks, no tipping movement can take place, as the blocks are firmly held at right-angles to the long axis of the wrench, or, as the blocks are at right-angles to the wrench, they are held by bearing surfaces parallel to their long axes (Fig. 135).

Applied to the inlay abutment, these facts prove, that movement of the anchor teeth in a mesio-distal direction may be prevented by constructing at least two broad bearing sur-

faces at right angles to the direction of movement. These, if the tooth stands in its normal position, will be parallel to the long axis of the tooth, that is, parallel to the direction in which the ordinary complicated inlay may be removed from the cavity. As this subject has been fully discussed in Chap. IV, it need not be repeated here. A very satisfactory way of increasing the area of the bearing surfaces, is to flatten the

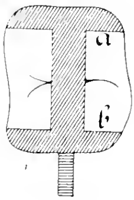


Fig. 136.

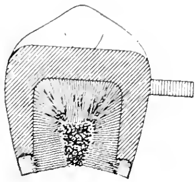


Fig. 137.

proximal surfaces of the tooth with a diamond disk (Plate V). Though these two surfaces (*a* and *b*, Fig. 136) ought to be parallel, it is not possible to make them so absolutely. They must converge slightly in order to prevent distortion of the impression during removal. A vertical section through a Car-

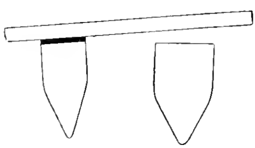


Fig. 138.

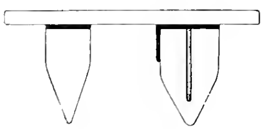


Fig. 139.

michael inlay (Fig. 137) shows the application of the wrench principle for the prevention of mesio-distal movement.

When only one anchor tooth is loose, the conditions are somewhat different. If oblique pressure is exerted upon the loose bicuspid, the tendency is to raise the inlay almost vertically out of the cavity of the molar (Fig. 138). The strain upon the inlay is proportional to the force exerted upon the bicuspid and to the amplitude of its movement. To prevent a dislocation of the distal end of the bridge, a very broad bearing surface on the mesial surface of the molar is necessary (Fig. 139). Such a surface offers more resistance than a post,

though the latter may also be used to give additional strength. If the bicuspid is firm and the molar loose, the bearing surface should be situated on the distal surface of the bicuspid. In other words, whenever one end of a bridge is in danger of being raised by the movement of the other anchor tooth, a broad bearing surface should be constructed upon that proximal surface of the firm tooth which faces toward the

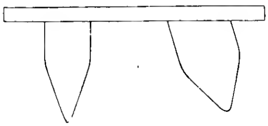


Fig. 140.

loose tooth. As a surface of this kind was recommended to counteract the effects of torsion (Figs. 121 and 122), it becomes evident that the broad proximal bearing surface fulfills a double purpose. Special attention should be paid to the effects of the movement of the anchor tooth just described, in constructing the posterior abutment of a bridge involving the

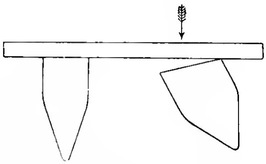


Fig. 141.

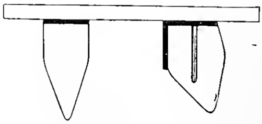


Fig. 142.

anterior teeth. Owing to the curve of the dental arch, a linguo-labial movement of an incisor will produce a vertical movement of an abutment situated in the cuspid or in a bicuspid (see p. 161).

The effect of an inclined position of one or both anchor teeth on the inlay abutment must also be taken into consideration. This condition is most commonly met with in lower second and third molars (Fig. 140). If vertical pressure is exerted upon a bridge supported by a tooth of this kind (Fig. 141), the latter is tipped still more. The bar rests on the distal margin of the tooth, while the mesial margin

draws away from the bar. The remedy in this case also, is a broad bearing surface (Fig. 142) against which the inclined tooth can find support. Such a surface is always preferable to a post. The latter may, however, also be used, and in effect, replace the second jaw of the wrench. Not only in this abutment, but also in others, may one of the jaws of the wrench be represented by a post (Fig. 131) or an extension into the pulp-chamber. But whenever possible, two flat surfaces of sufficient area should be used. In pulpless teeth with crowns weakened by decay, this is not always practicable, posts must therefore often be relied upon.

Vertical Movement of the Anchor Teeth.

Though even the normal tooth has a slight movement in this direction, it is only in the advanced stages of alveolar absorption that the movement becomes very noticeable. If both abutment teeth move the same distance, the anchorage of the bridge is not endangered. When but one tooth is loose, the strain upon the firm tooth becomes enormous. If the abutment is strong enough to transmit the strain, the firm

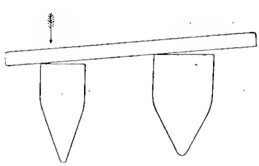


Fig. 143.

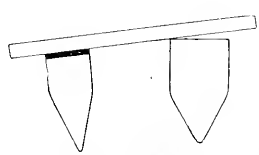


Fig. 144.

tooth will sooner or later loosen to such an extent that failure of the whole bridge becomes inevitable.

The diagram (Fig. 143) shows, that when pressure is exerted upon the bar over the loose tooth, spaces are formed between the distal margins of both teeth and the bar. As, however, a loose tooth is easily tipped, it will remain at right-angles to the bar, and the effect of the action will be that of a powerful lever of the first class, the mesial margin of the firm tooth acting as the fulcrum (Fig. 144). Applying the wrench principle to counteract this force, large bearing surfaces, mesially

and distally, as well as a strong post, should be used (Fig. 145). If the crown of the firm tooth is extensively decayed, an inlay abutment is contraindicated. A strong shell-crown should be used in its place.

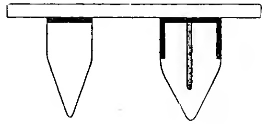


Fig. 145.

Whenever an anchor tooth is loose, the inlay abutment must cover the whole occlusal surface. It has been shown (Chap. IV and Fig. 53), that the anchorage of a self-retentive inlay is weakest in the direction opposite to that in which

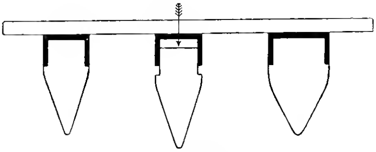


Fig. 146.

the inlay was inserted into the cavity. If therefore, the inlay is firmly held in position by the bridge, and the force of mastication accidentally exerted only upon an exposed cusp of the loose tooth, the latter will be pressed into its socket

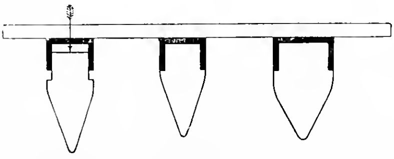


Fig. 147.

and the inlay forced out of the cavity in the direction of its least resistance. Such conditions, necessary for the vertical dislocation of a properly constructed inlay abutment, are always present when the bridge is supported by more than two anchor teeth, unless, and this is rarely the case, all the teeth are of exactly the same degree of firmness. Figs. 146 and 147 show

how either the middle or an end abutment tooth may be depressed. If the inlay is to be attached to the bar, it must cover the whole occlusal surface, so that in mastication no force can be exerted directly upon this surface of the loose tooth. The cusps should be bevelled with a diamond disk as shown in Plate VI.

The Flexible Abutment.

As a rule, the writer, in cases as those just described, prefers to use a loose or flexible abutment; that is, an inlay of special form upon which the bar simply rests, the bridge being otherwise supported by one or more rigid abutments.

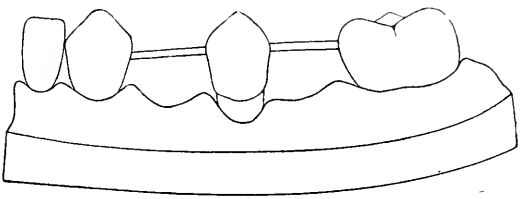


Fig. 148.

If the bicuspid in Fig. 148 possesses vertical movement, a cavity is excavated extending across the middle of the occlusal surface and involving the proximal surfaces to below the contact points. The finished abutments in the cuspid and

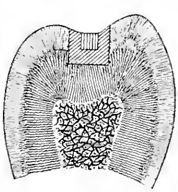


Fig. 149.

in the molar are then connected with a square platinum-iridium bar of sufficient strength, which extends through the excavated occlusal cavity of the bicuspid (Fig. 149). With the bar in position a wax impression is taken. The inlay is cast and set into place. The bridge is then finished in the usual manner,

by casting occlusal surfaces, with or without removable porcelain facings, onto the bar. When the bridge has been set, the bicuspid is free to move in a vertical direction. Mesio-distal movement is prevented by the adjoining teeth of the bridge (Fig. 150), while the flat surfaces of the bar prevent bucco-lingual motion (Fig. 149).

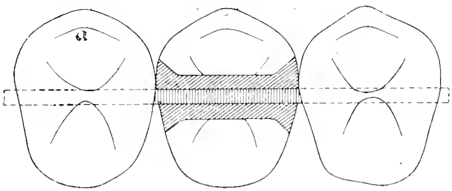


Fig. 150.

When the conditions are similar to those shown in Fig. 147, it is not advisable to let the bar rest merely on the occlusal surface (Fig. 154). Especially is this true, when the tooth adjoining that of the abutment is also loose. In this case, the end of the bar must be bent, or a piece soldered on, at right-angles, and be extended well toward the cervical margin.

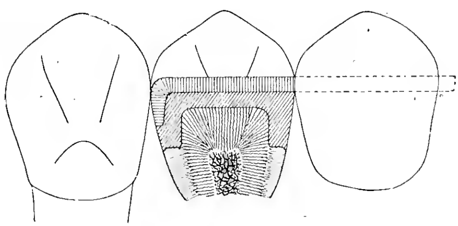


Fig. 151.

The inlay is constructed as described above, and set before the introduction of the bridge (Fig. 151).

The flexible abutment may also be used to advantage in connection with firm teeth. Such bridges with but one rigid abutment, though not often met with in practice, are by no means new.*) Owing to its many advantages, especially in

*) W. S. Davenport. Dental Bridge and Pier Construction. Trans. N. Y. Institue of Stomatology, 1902.

connection with inlay work, this type of bridge deserves full recognition by the profession at large.

The most common form of flexible abutment is the lug (Fig. 152). Its bearing surface is, however, too small, and there

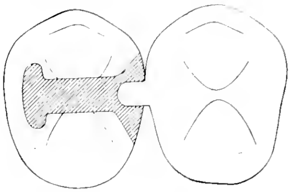


Fig. 152.

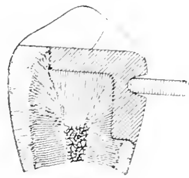


Fig. 153.

is the constant danger of the abutment tooth moving away and leaving that end of the bridge entirely unsupported.

The abutment shown in Fig. 153, a variety of socket joint, at one time used by the writer, is open to the same objection. Beside this, strong distal movement (tipping) of the molar invariably forced out the inlay in a vertical direction, after a longer or shorter time. Only where the length of the bar was equal to the width of one bicuspid, and both anchor teeth were perfectly firm, has this form of abutment been successful in practice.

If both, the tooth adjoining the abutment and the tooth supporting the other end of the bridge, are firm, the flexible

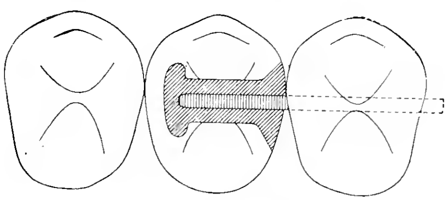


Fig. 154.

abutment shown in Fig. 154 may safely be depended upon. (Section same as Fig. 149.) The cavity is easier to prepare than that of Fig. 151, as but one proximal surface is involved. The construction of the inlay is also less difficult, especially about the end of the bar, as this is here situated upon the easily accessible occlusal surface.

Though possessed by all flexible abutments more or less, the advantages enumerated below refer particularly to the forms shown in Figs. 150, 151 and 154.

The flexible abutment interferes but very slightly with the physiological movement, while at the same time preventing any abnormal motion of the anchor tooth. The lateral movements of the tooth (Fig. 150) are in direct ratio to those of the end abutment teeth. If these are firm, the loose tooth cannot move beyond physiological limits. (Compare Fig. 148 and 149.)

When the flexible abutment is situated at the end of a bridge with but two piers, lateral displacement is dependent upon the firmness of the other anchor tooth and upon the length of the bar. With a long bar a perfectly firm tooth, owing to a slight rotary motion in its alveolus, will permit the loose tooth to move laterally somewhat more than normal. The same is true, however, of every bridge, even with rigid abutments.

Mesio-distal movement can occur only within physiological limits, and in a normal manner. The distance is determined by the movement of the firm anchor teeth (Figs. 148 and 150), or by the firm adjoining tooth (Fig. 154). The anchor tooth carrying the flexible abutment, not being attached to the bar, does not follow the movements of the bridge bodily, but moves in the arc of a circle (Fig. 120).

Vertical movement is in no way interfered with. This is one of the most important advantages of this type of bridge. When there are but two abutments, each tooth moving independently, can assume a position in which all points of the root bear equally against the walls of the alveolus when force is exerted upon any point of the bridge. The peridental membrane will remain healthy, and no inflammatory changes in the bone, due to localized pressure, will take place.

Another advantage of the flexible abutment is, that inclined anchor teeth do not cause serious difficulties in the construction of the bridge (Fig. 155). Each abutment being made seperately, can readily be brought into place. If two inlay abutments are used, each one while being set, can be

adapted perfectly to the margins of the cavity; a feat difficult to accomplish with rigid abutments in the form of inlays.

In determining the force exerted upon an inlay abutment, another factor beside the movement of the teeth must be considered, that is, the width of the masticating surface of the bridge suspended between the abutments. If this surface is too wide, pressure exerted at but one point near the edge (*a*, Fig. 150) will set up a severe torsional strain in the bar, which in turn transmits it to the inlay. Such surfaces should therefore be made slightly narrower than normal, especially near the flexible abutment. Attention should also be paid, that the bar or central line of occlusion divides this surface equally, as pressure exerted on the entire masticating surface

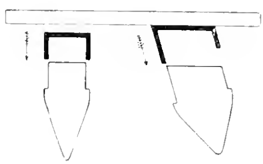


Fig. 155.

of the bridge will then produce no torsional strain. With unequally divided surfaces, this is, however, not the case.

In discussing the effects of strain upon inlay abutments, only those in the molars and bicuspids have been considered. All that has been said, applies also to abutments in the anterior teeth. Another factor, however, plays an important part. The bicuspids and molars are situated in a straight line, while the anterior teeth occupy a position on the arc of a circle. This difference in alinement produces a difference in the distribution, magnitude, and direction of the strain exerted on the abutments and on the bridge. To describe the difference of effects in detail, would neccessitate the repetition of much that has already been explained. By following the description of the strain exerted upon the molars and bicuspids, anyone who is sufficiently interested can for himself determine the effects on the anterior teeth. The task becomes very simple if a wire, the length of the bridge, is bent in conformity to

that part of the dental arch in which the bridge is situated. By moving one end or the middle of the wire, reproducing the movements of the abutment teeth, the effects upon all parts of the bridge can readily be determined.

To specify the exact conditions in which inlay abutments are indicated, is not possible. A rigid inlay abutment may safely be used when the space to be bridged does not exceed the width of two bicuspids, and when the anchor tooth is firm and possesses a strong crown. The use of the flexible inlay abutment is not so limited, especially when there are more than two anchor teeth. In some favorable cases of this kind, one rigid and two flexible abutments may be used, as in Fig. 148 when the bicuspid as well as the other anchor teeth are firm.

It is not the intention of the writer to make a plea for the extensive use of the inlay abutment. But there are cases where it undoubtedly offers an ideal form of anchorage. When a space between two healthy, reasonably firm teeth is to be bridged, say a space due to the premature loss of the first molar, an inlay bridge, constructed as follows, is to be preferred to any other form of bridge-work. In such cases the writer would recommend a rigid inlay abutment in the second molar, and a flexible abutment in the second bicuspid. The pulps in both teeth being intact, they should in no way be interfered with. Recurring to the principle of the wrench, the construction of large bearing surfaces upon the mesial and distal surfaces of the molar, parallel to the long axis of the tooth, becomes necessary. The quickest and most painless way of preparing these surfaces is to flatten the tooth with a diamond disk (Fig. 136, or as shown in Plate V). One or both proximal cavities should be deepened slightly (somewhat less than shown in Plate V) in order that the inlay may resist torsional strain. The occlusal surface is cut out to a sufficient depth with a knife-edged stone, so that the platinum-iridium bar does not interfere with the bite, and lies well within that part of the inlay which fills this cavity (Fig. 156).

The flexible abutment is constructed either as in Fig. 151 or in Fig. 154. If both the bicuspid and molar are firm, the

latter method is used, if the bicuspid is somewhat loose the former should be employed. The platinum-iridium bar, representing the frame-work of the bridge, should bear upon each abutment so, that any force exerted upon it vertically, is transmitted equally to the lingual and buccal halves of the anchor teeth. The bar should be square and be about 2 mm. ($^1/_{16}$ inch) in thickness. One end of the bar is bent so, that when laid upon the occlusal surfaces of the abutment teeth, the bent end extends into the distal cavity of the molar parallel to the axial wall and almost to the cervical margin (Fig. 156). Inlay wax is introduced into the cavity and roughly modelled. The bar, previously roughened, is then warmed and forced

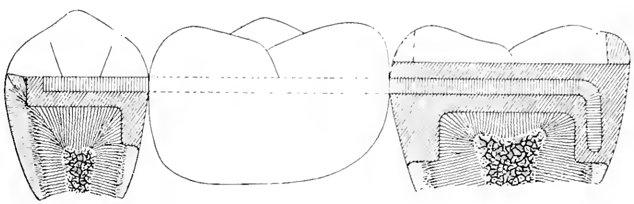


Fig. 156.

into place, the impression finished, and the inlay cast onto the bar in the usual manner. In difficult cases an indirect impression is taken or a stone model made, and the wax model again tried in the mouth. In order that the alinement of the other end of the bar may be correct while taking the impression of the molar cavity, the writer excavates the occlusal surface of the bicuspid only so deep, that the bar rests in the position that it is to occupy later. After the rigid abutment has been cast, the cavity of the bicuspid is completely excavated, an impression taken with the bar in place, and the inlay cast. The margins of both inlays are thereupon burnished, and the one in the bicuspid set into the cavity. At this stage the bridge consists of two perfectly fitting inlays, the one rigidly and the other loosely connected with the bar. Upon the latter a tooth is modelled in wax, and then cast. If desirable a removable porcelain facing can be used.

In conclusion the writer wishes to emphasize, that the inlay abutment is not applicable to every case, but that whenever it is used, it should be properly constructed with due regard to the strain which will be put upon it. In determining the proper form, it is always advisable to regard the inlay abutment as a combination of two wrenches, the one acting parallel to the long axis of the tooth to prevent tipping, the other at right-angles to the first, to prevent rotation and lateral movement.

It is a regrettable fact, that in the construction of dental bridge-work but little thought is given to the distribution of force within the structure. The dentist should follow the example of the engineer, who calculates the stress and strain of every part of a bridge before begining with its construction.

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